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CHEMICAL ENGINEERING PROGRESS

MARCH 1959

IN-PLANT POLLUTION CONTROL

current practices and costs—page 37

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March 1959 Volume 55, No. 3

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Cover by Paul Arlt.

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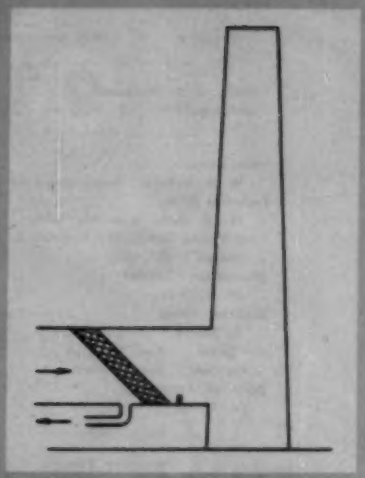

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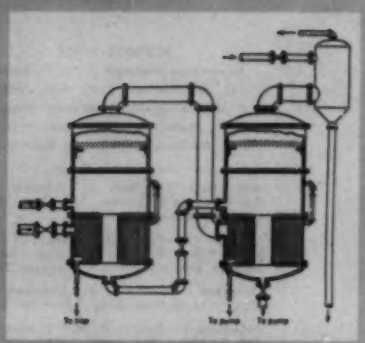

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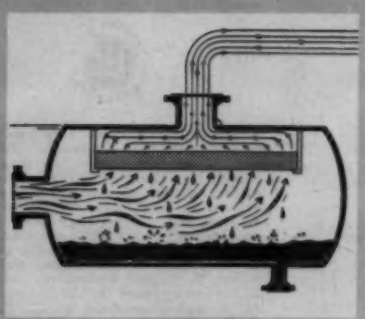

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Evaluated weather data for cooling equipment design

Fluor Products Company has recently published a manual entitled, *Evaluated Weather Data for Cooling Equipment Design*, which should be of value and interest to the design engineer. Weather data is explained in a clear concise manner to assist the engineer in the evaluation of this information for the design and selection of cooling towers, and evaporative condensers or coolers. While the weather data is limited and not adequate for the design of air conditioning installations, it does provide valuable additional information to that now available to the engineer.

The manual includes valuable tables, charts, and maps, mainly of summer wet and dry bulb temperatures, wind data, and the coincidence of dry bulb values with high wet bulb values. Temperature variations as factors in the design of cooling equipment are discussed along with practical methods for interpolation of data between weather stations.

The information presented is based on a study of more than 10-million individual observations from 434 separate geographical locations in Canada, the United States, and Mexico for periods ranging from 5 to 10 years. Nearly half of the observations are for a full 10 year period from 1948 through 1957. Analysis has been accomplished by modern electronic tabulating equipment.

The presentation of wet bulb design values and prevailing wind data during high wet bulb temperature periods has been well done and should greatly assist the engineer for design of installations in the United States, southern Canada, and most of Mexico.

The presentation of coincident dry bulb values with high wet bulb values on psychrometric charts for 49 locations in the United States is a real contribution and of great value to the design engineer. It clearly demonstrates a fact known to meteorologists, but not too well recognized by design engineers, that maximum dry and wet bulb temperatures at most locations do not occur at the same time. It should also assist the engineer in a more economical design of air conditioning installations. Where air cooled exchangers are combined with cooling tower systems, more economical design conditions may be selected by the use of this data.

The information on dry bulb design values is limited and is not adequate for economic selection of design temperatures for air cooled exchanger installations. If the dry bulb design values were treated with greater thoroughness, the manual would be of more value in the design of all types of cooling equipment. The price of this manual is $35.

FREE RADICALS IN SOLUTION, Cheves Walling, John Wiley & Sons, New York (1957), 627 pp., $14.50.

Reviewed by J. L. Franklin, Jr., National Bureau of Standards, Washington, D. C.

Professor Walling introduces the subject of free radicals in solution with a chapter dealing with structures

continued on page 8

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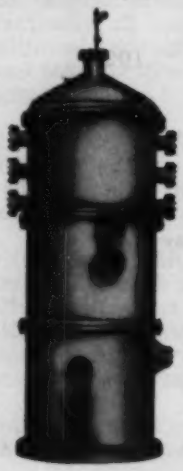

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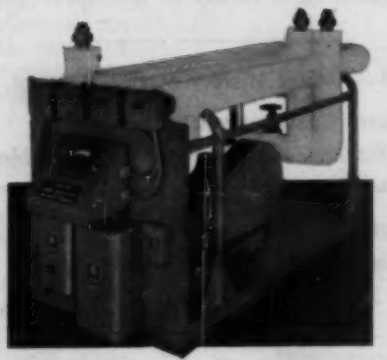

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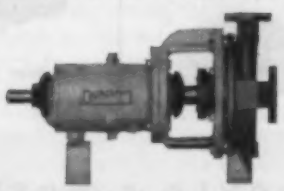

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marginal notes

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and physical properties and one dealing with the general types of reactions involving radicals, their rates and energetics, and the important question of bond dissociation energies. These are followed by several chapters on various aspects of polymerization and then by discussions of other types of chain reactions. The final two chapters discuss nonchain reactions of free radicals.

Professor Walling's approach to his subject is through reaction kinetics. Early in the book he develops the rate equations for polymerization reactions and subsequently he relates the kinetics of other chain reactions to these basic expressions. He thus provides the reader with a quantitative approach that is lacking in most classical treatises on chemistry. His treatment also achieves a high degree of coherence.

Some errors and ambiguities can hardly be avoided. A few that should be mentioned are:

On p. 42 the fact that dissociation energies are greater at ordinary temperatures than at O°K. is attributed to a loss in degrees of freedom on dissociation. The reverse is, of course, true. The products of dissociation gain translational and rotational degrees of freedom at the expense of vibration and so at temperatures below 300-500°C. have greater heat content than the undissociated molecules. This increase in heat content upon dissociation results in the heat of dissociation being greater at ordinary temperatures than at O°K.

2. On p. 43 the heat of reaction *(31)* is shown incorrectly as positive and this leads to an erroneous value for the net heat of the cycle.

In several places, and especially in chapter three, numerical values of rate constants are given without units. This omission is rather annoying and surely the economy achieved is small.

All these criticisms are, of course, minor and have little to do with the value of the book. The style is lucid and readable. It is recommended as a worthwhile addition to any engineer's bookshelf.

VAPOUR-LIQUID EQUILIBRIUM—E. Hála, J. Pick, V. Fried and O. Vilim—2nd ed. (Translated by G. Standart) —Pergamon Press, New York, London, Paris, Los Angeles (1958), 402 pp, $14.00

Reviewed by S. B. Adler, The M. W. Kellogg Co., New York, N. Y.

To the reviewer's knowledge this is the first book exclusively devoted to the subject of liquid-vapor equilib-

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D. S. GLASS—SALES ENGINEER

Mr. Glass graduated from Illinois University with a B.S. Degree in Chemical Engineering. For three and one-half years, he worked in the midwest as a process engineer with a petroleum additive manufacturer.

He has been with National Carbon Company since 1953. He has worked on the development and design of chemical process equipment, prepared technical design proposals and worked directly with users on the installation of carbon, graphite and "Karbate" impervious graphite equipment. Since late 1958, he has been a field engineer covering the northeastern states.

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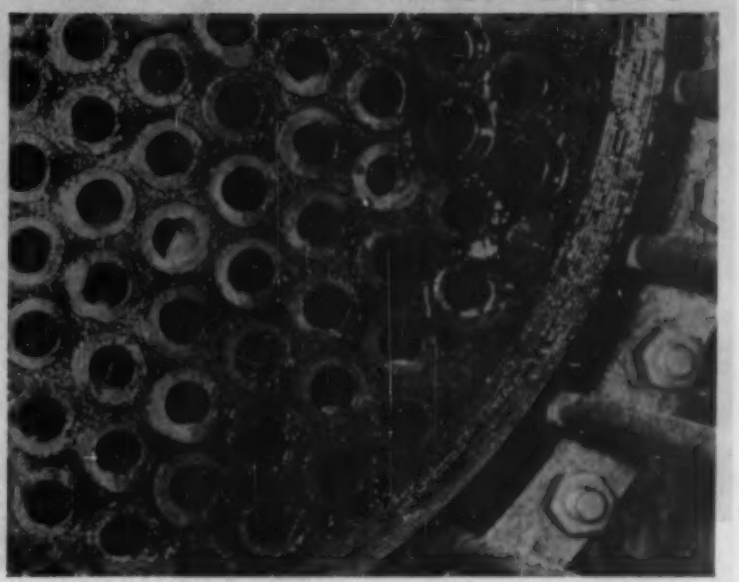

Tube sheet of a reboiler in service twelve years. Some replacement tubes are shown. Most tubes are original ones installed in 1946. Machining marks made in 1946 are visible on the impervious graphite tube sheet.

"Karbate" impervious graphite shell and tube heat exchangers provide economic service life as reboilers handling 45-55% sulfuric acid-organic solution. Sixteen of these reboilers were installed by a major chemical company in 1946.

The sulfuric acid flowing through the tubes of the reboilers contained contaminants. Eventually, stubborn carbonaceous deposits formed inside the "Karbate" impervious graphite tubes and had to be removed periodically. This was done mechanically by drilling and sandblasting techniques.

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REBOILERS REPAIRED (per year)	23	9

To check performance of these units, records were kept starting in 1950 covering both cleaning and repairs.

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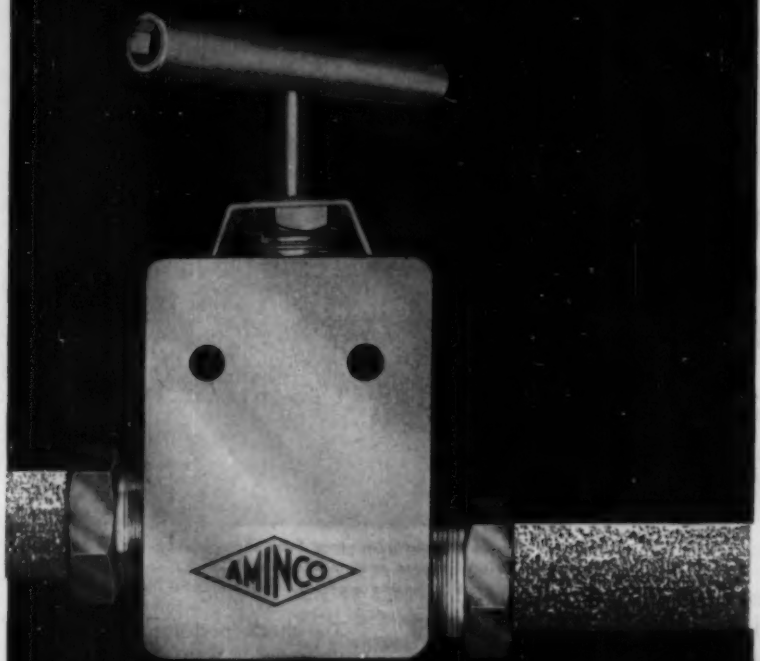

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marginal notes

from page 8

rium; i.e., to the obtaining, analyzing and correlating of the experimental data. Actually this book is a second edition which was prepared specifically for English translation. The first edition was published abroad in 1954. Unlike many translations, the English is excellent. The four authors are in the Department of Physical Chemistry, Institute of Chemical Technology in Prague, Czechoslovakia.

The book is divided into three main sections: (1) A theoretical section—the thermodynamics of solutions of non-electrolytes; (2) A comphehensive coverage of laboratory technique involved in obtaining experimental data; and (3) An index to bibliography of data in the field through February 1957.

The 143-page portion on thermodynamics is extremely thorough. It will be of interest to chemical engineers and physical chemists whether or not they are engaged in the field of liquid-vapor equilibria. The treatment of the equations of Wohl, Scatchard, Van Laar, Margules, White, Li & Coull, Redlich & Kister, etc., is the most comprehensive found anywhere. Works published abroad, which might otherwise be missed entirely, are brought to the reader's attention.

The section on laboratory technique presents in detail the four main schemes for determining experimental data: the circulation, static, dew and bubble point, and flow methods. Also included are vapor pressure and boiling point measurements. Determining the thermodynamic consistency of the laboratory data and the smoothing of data by the method of least squares also receive attention.

UNIT PROCESSES IN ORGANIC SYNTHESIS, Edited by P. H. Groggins, Fifth Edition (1958), McGraw-Hill Book Company, Inc., New York, N.Y., 1070p. $17.50.

Describes scientific and technological principles used in converting organic raw materials into usable products. Processes discussed are nitration, amination by reduction, ammonolysis, oxidation, hydrogenation, hydrocarbon synthesis and hydroformylation, esterification, hydrolysis, alkylation, and polymerization.

THE PETROLEUM CHEMICALS INDUSTRY, Richard F. Goldstein, John Wiley & Sons, Inc., New York, N.Y., Second Edition (1958), 458p. $16.50.

Describes major products and basic chemistry of the processes used; also indicates commercial possibilities. In-

cluded are new chapters on statistics and economics, and on history of the petroleum industry.

ADMINISTRATION OF SALARIES AND INTANGIBLE REWARDS FOR ENGINEERS AND SCIENTISTS, John W. Riegel, Publications Distribution Service, University of Michigan, Ann Arbor, Michigan (1958) 105, 84p. $6.00. Two surveys (in one volume). Reports number 8 and 9 of University of Michigan Bureau of Industrial Relations.

Specific aspects investigated are job activities, actions of immediate supervisor, salaries, intangible rewards, working relations with associates, company assistance to professional development, attitudes toward collective bargaining and administration of technical programs.

DIGITAL TECHNIQUES FOR COMPUTATION AND CONTROL, Martin L. Klein et al., Instruments Publishing Co., Inc., Pittsburgh, Pa. (1958). 394p. $6.00.

Surveys basic techniques, covering code arithmetic, logical networks, multiplexing, conversion, data reduction, digital process control, two-terminal relay circuits, counting techniques, digital computers of all types, computer programming, digital differential analyzers, and combined analog-digital equipments. Descriptions of components and available commercial equipment.

CONTROL SYSTEM COMPONENTS, John E. Gibson and Franz B. Tuteur, McGraw-Hill Book Company, New York, N.Y. (1958), 493p., $12.00.

An analytic treatment of the most commonly used components in feedback control systems. Included are recent advances in magnetic amplifiers, transistors, hydraulic and pneumatic systems. There are sections on network synthesis, thyratron amplifiers, a system analysis of valve-operated hydraulic systems, and relay amplifiers.

SUCCESSFUL PROCESS PLANT PRACTICES, Robert L. Davidson, McGraw-Hill Book Company, New York, N.Y. (1958), 302p. $10.00.

Solu ion of problems relating to managing, scheduling, operating, maintaining, and repairing in the process industries. Pumps, towers, reactors, piping, valves, motors, instruments, exchangers, condensers, machine shops, and insulation are treated. Working data is provided, such as dimensions, operating conditions, materials of construction, and tools.

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(Formerly located at 415 Lexington Ave., N. Y. 17, N. Y. and our phone number was MUrray Hill 2-8770)

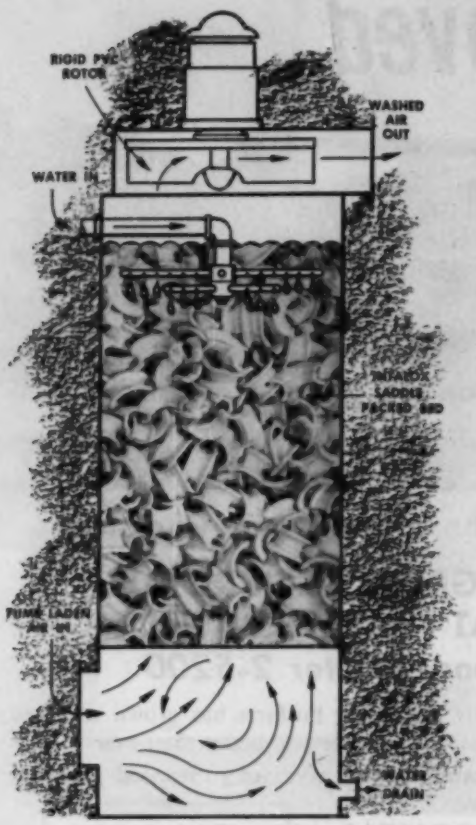
SINCE 1936

For more information, turn to Data Service card, circle No. 102

FOUR WAYS TO HANDLE

● Absorption of noxious fumes by wet bed scrubbers is generally accepted as the most satisfactory method where virtually complete fume removal is required. With the development of packings of high efficiency, such as Intalox Saddle Packing and Metal Pall Rings and improved liquid distribution methods, fume scrubbers of high capacity yet occupying little space and operating at low cost have become practical.

On these two pages are illustrated and briefly described both standard and custom-built fume scrubbing units of our manufacture. Full engineering data is available on request. U. S. Stoneware's Engineering Department will be glad to work with you in designing fume removal systems to meet your specific needs.



"CYCLONAIRE" Fume Washer

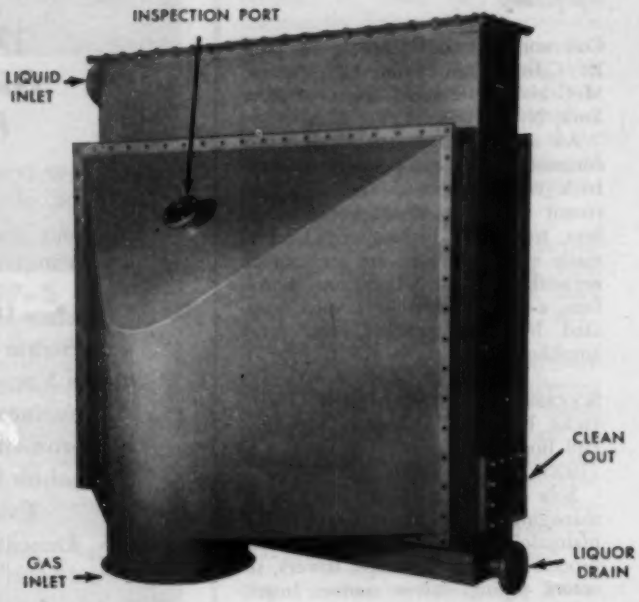
Designed primarily to handle relatively mild fume problems in laboratories, special departments, etc., the Cyclonaire is made in four sizes with rated capacities of 750, 1650, 3500 and 6000 cfm. It will effectively remove up to 99% of fumes (where the concentration of gases is 1% or less). The Cyclonaire comes complete with blower, motor drive unit, and Intalox Saddle Packing. The unit is constructed of 12 gauge steel, lined with 3/32" thick Tygon sheet plastic. The rotor is rigid polyvinyl chloride plastic. All exterior surfaces are protected with Tygon Paint.

The "Cyclonaire" can be equipped with mist or dust eliminators or provided with recirculating pumps. Two units can be arranged in parallel to handle additional cfm, or in series for heavier fume concentrations.

The "CROSS-FLOW" Fume Scrubber

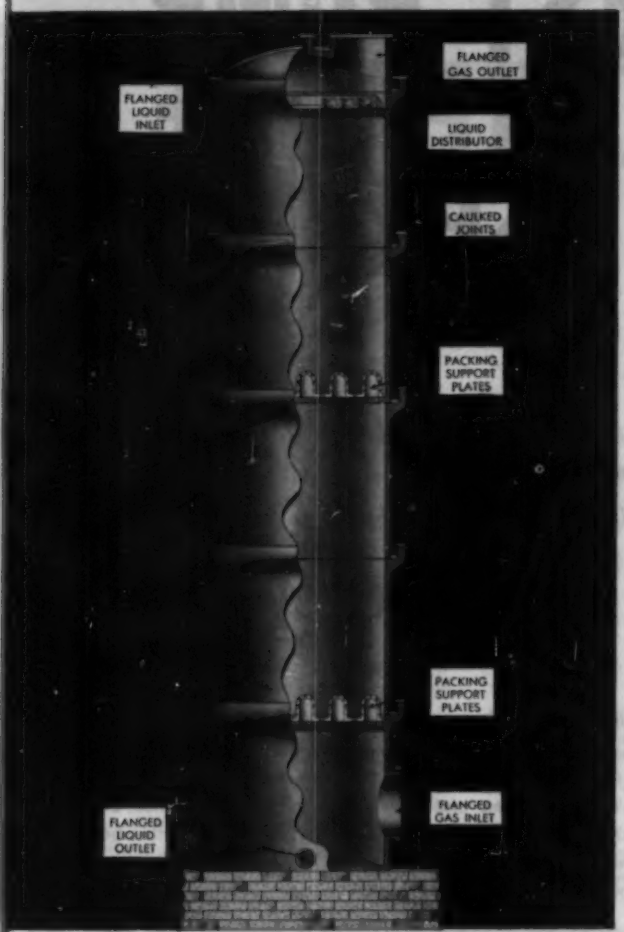
The "Cross-Flow" Fume Scrubber provides high efficiency in relatively small space. It is so designed that the gas flow and liquid flow are perpendicular to each other . . . the liquid flow vertical, gas flow horizontal. The effective liquid distribution over a cross-section area that is large in relationship to the thickness of the packed bed results in a highly active surface area capable of handling gases at high velocity rates with minimum pressure drop.

The "Cross-Flow" Fume Scrubber is built in six standard sizes with capacities ranging from 3,000 to 32,000 cfm. The unit is fabricated from heavy steel plate lined with 3/32" Tygon. Distributor is rigid plastic. The screen grid can be stainless steel or plastisol-covered wire mesh.



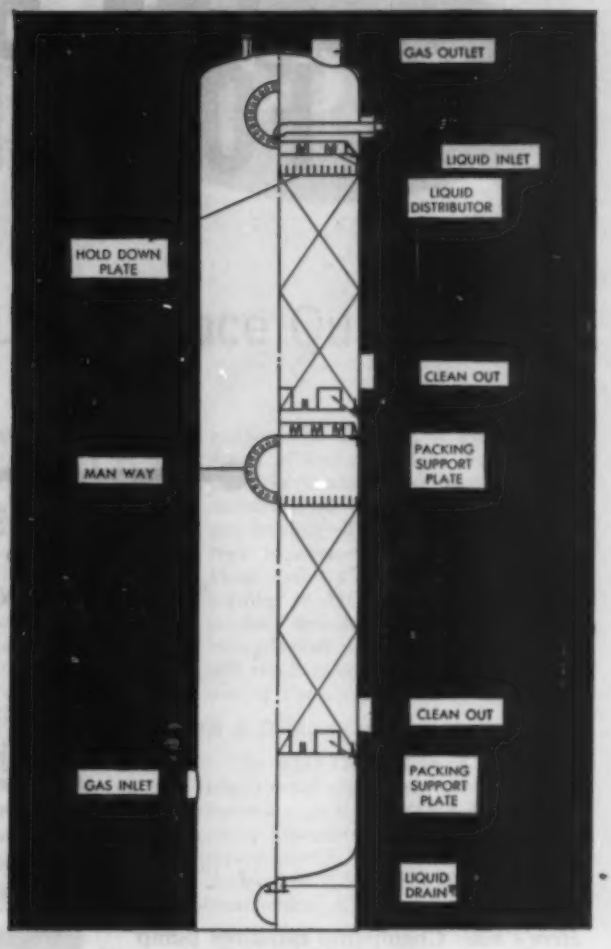
The unit illustrated above was designed for roof mounting, hence the gas inlet is located at the bottom. The unit, however, can be furnished with gas inlets located as desired.

FUME REMOVAL PROBLEMS



Ceramic Fume Washers

For some applications, fume scrubbers made from chemical ceramics represent the best and most economical approach. Ceramic fume scrubbers can be provided in diameters up to 48", in heights up to 60 feet or more. Ceramic support plates, ceramic distributors, and ceramic pipe and fittings complete a virtually universal corrosion-resistant fume removal unit. Standard towers are made with either bell-and-spigot construction or with cemented-on-metal flanges and are available in chemical porcelain, standard stoneware or "Ceratherm-550" heat-shock resistant stoneware.



Custom-built Metal Scrubbers

By far the largest number of fume removal applications involve the use of equipment custom designed and built to the user's specific requirements. The unit illustrated is typical of many such towers we have built in sizes ranging up to 8'-10' in diameter and as much as 80 feet high. The units may be lined with Tygon sheet lining or rubber, or unlined. Either metal, carbon, or ceramic support plates and distributors may be employed. Packing may be ceramic or carbon Intalox Saddles or Metal Pall Rings according to the nature of the gas and scrubbing agent.

Continued research in packed column technology enables U. S. Stoneware to offer fume scrubbers of most advanced design and proven efficiency. The results of our engineering investigations and our practical "know-how" are always available, with no implied obligation to design and operating engineers. Write Engineering Dept., U. S. Stoneware, Akron 9, Ohio, or one of our major branches.

U. S. STONEWARE

AKRON 9, OHIO

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377-F

For more information, turn to Data Service card, circle No. 90

THE BEST PUMP FOR LEAKPROOF SERVICE

Chempump eliminates costly and dangerous carbon tetrachloride leakage

Proved by this installation . . . at the chlorinated products plant of a major chemical company, Chempumps are used to handle carbon tetrachloride. Conventional centrifugals, formerly used to pump the fluid from storage tanks to drums and tank cars, ran up maintenance and downtime costs . . . were constantly leaking. Chempumps—the *best* pumps for leak-proof service—solve solvent leakage problems . . . save users thousands of dollars per year.

Here's how: Chempump combines pump and motor in a single, leakproof unit . . . no stuffing boxes or shaft sealing devices are required. Available in a wide choice of materials and sizes, they handle fluids ranging from Dowtherm to liquid oxygen. Chempumps are in use by the thousands . . . demonstrating every day why these field-proven pumps, backed by years of design and construction experience, are your assurance of *dependable* operation.

Write now . . . for "request for quote" data sheet . . . to Chempump Corporation, 1300 E. Mermaid Lane, Phila. 18, Pa.

Chempump

First in the field... *process proved*

For more information, turn to Data Service card, circle No. 13

SCOPE

New Plant Construction Pace Quickening?

Announcements of decisions to invest in new chemical production plant have been coming through in increasing volume since the turn of the year. Does this conflict with the fairly conservative results of a survey recently published by MCA on completed, under construction, and planned plant construction? Its too early to spot an established trend, but here is a sampling of recent announcements:

About $24 million has been budgeted by Eastman Kodak for capital improvements at its Tennessee Eastman and Texas Eastman Divisions for stepped-up production of plastics, fibers, industrial chemicals . . . **First large-scale commercial plant** for manufacture of boric oxide (high-energy fuel ingredient) will be built by American Potash & Chemical at Trona, Calif. . . **Uranium dioxide for nuclear fuels** will be made in a new plant to be erected by Spencer Chemical near Pittsburg, Kansas. . . **A large liquid oxygen** and nitrogen plant will be built by Linde (Union Carbide) near the Redstone Arsenal, Huntsville, Alabama. . . **A $2 million Air Force contract** has gone to Stauffer-Aerojet for design, construction, and operation of a large pilot plant near Sacramento, Calif. A new process is expected to reduce "greatly" the production cost of liquid boron fuels . . . **A new company, jointly owned** by Hercules Powder and Stauffer Chemical, will make more than 1 million pounds a year of aluminum alkyls-plant site is not yet set. . . **Two new intermediate chemicals,** pyromellitic acid and pyromellitic dianhydride will be turned out in a new unit to be built by Du Pont's Explosives Dept., at its Repauno Works, Gibbstown, N. J.

Record in 1958

A record total of $1.775 billion in privately-financed chemical production facilities were completed in 1958, according to a recent survey by the Manufacturing Chemists' Association. Previous high was $1.3 billion in 1957. An additional $1.054 billion will be spent for projects now in the works, says the survey report, and a total of $464.090 million for projects slated for ground-breaking in the near future and for completion before 1961. Total chemical plant construction for the three-year period, 1958-60, is estimated at $3.293 billion.

The combined estimate represents a total of 802 projects by 287 companies in 432 communities in 43 states. Excluded from the scope of the survey were foreign construction, government-financed construction, office, warehouse, and separate service facilities, and installation or modification of equipment in existing facilities.

Planned construction down

The $1.518 billion total for the Under Construction and Planned categories (see table) is more than $1 billion under the $2.54 billion for the same categories in last year's survey results. The decrease is ascribed by MCA as due in part to construction cutbacks made during the recession months of mid-1958, in part to a general leveling-off of the chemical industry's requirements for new facilities. Most industry leaders however, according to MCA, expect that "new product demand resulting from recent technological and sociological trends will result in continued steady expansion of chemical-producing facilities."

R & D outlay up

The $157.170 million in the new-laboratory category represents a sharp increase over the $107.2 million laboratory expenditure listed in last year's survey results. The 1958-60 figure includes $27.425 million for planned construction; $59.6 million for under construction; and $70.145 million for completed construction.

Dollar sales steady

Indications at present are that the chemical industry's 1958 sales will total $23.247 billion, only 0.7% under 1957's record total.

MCA Chemical Industry 1958 construction survey

Category	Planned	Under Construction	Completed	Total
		(By Thousands)		
Fertilizer Chemicals	$41,000	22,200	52,575	115,775
Inorganic Chemicals (General)	40,800	327,640	428,770	797,210
Laboratories	27,425	59,600	70,145	157,170
Metals	18,100	15,450	141,207	174,757
Organic Chemicals (General)	152,940	246,730	401,763	801,433
Petrochemicals	22,000	53,050	164,700	239,750
Plastics & Resins	54,700	173,850	164,195	392,745
Synthetic Rubber	....	29,000	24,523	53,523
Synthetic Fibers	59,500	54,400	140,300	254,200
Miscellaneous	47,625	72,245	187,345	307,215
Totals	$464,090	$1,054,165	$1,775,523	$3,293,778

Slurry process termed salt water conversion breakthrough

Long-tube, vertical multiple-effect distillation has been selected as the process to be used in the first of five plants authorized by Congress last year for projects to convert salt or brackish water for industrial, municipal, or agricultural use. Site of this first demonstration plant has not been announced as yet: sea water plants are, however, scheduled for the East, West, and Gulf Coasts, and brackish water plants for the Southwest and the Northern Great Plains area.

Key to selection of the distillation process is said to have been solution of the problem of "scaling" by recycling salt crystals through the system; the crystals act as "seeds" for further crystal growth and thus prevent deposition of salt on the tubes of the distillation unit. Development of the process has been in progress since 1955, when the Office of Saline Water contracted with W. L. Badger & Associates of Ann Arbor, Mich., for preliminary study work. Pilot plant work has been carried out at Harbor Island, N.C., at facilities made available by International Nickel; the evaporator used was furnished by Swenson Evaporator, a division of Whiting Corp. of Harvey, Ill.

"We have reason to hope," said Fred A. Seaton, Secretary of the Interior, "that this demonstration plant will produce fresh water from the sea for less than $1 dollar per 1,000 gallons. This represents a reduction of about 50 percent under the cost of converting sea water in the most efficient commercial conversion plant in operation in the world today," continued Seaton.

First municipal plant dedicated

A very different process is being employed in what is said to be the nation's first municipal water desalting plant—the recently-dedicated 28,000 gallon-per-day membrane-type plant in Coalinga, Calif., installed by Ionics, Inc., of Cambridge, Mass. Probable cost of brackish water conversion in the unit is estimated at between $1.50 and $2.00 per 1,000 gallons. This compares more than favorably with the $7.05 per thousand gallons that Coalinga has been paying for tank-car-transported drinking water.

Atomic reactor plus distillation

A 20 million gallon-per-day conversion plant, employing a pressurized-water reactor of 350 MW capacity and a multi-stage flash distillation system is being studied by Fluor Corp. Part of the cost of the study is being borne by the State of California. This was brought out recently in a talk on California's Activities in Saline Water Conversion delivered, before a meeting of the Southern California Section of A.I.Ch.E. by Maurice B. Andrew of the California Department of Water Resources. A similar study will also be made of a 1 million gallons-per-day plant, using data developed on the larger plant, added Andrew. Design and cost estimates in the study will be based on data representing the characteristics of a typical California coastal site. Other possibilities being studied in California, according to Andrew, are solar distillation, ion exchange, ultra-filtration, and multi-effect vapor compression distillation.

Washington notes

An evacuated powder, said to be much superior to vacuum as an insulator, is said to be under development at the Bureau of Standards—application is seen in storage and transport of liquefied gases . . . $5 million may be spent by the Government to erection of a plant to produce graphite "whiskers", said to be extremely strong, with excellent high-temperature resistance . . . Availability of Krypton-85 for civilian use has been increased to 1,000,000 curies per year . . . A National Science Foundation grant of $57,600 has gone to three U. of Wisconsin engineers for basic studies on liquid fuel combustion . . . Consolidation of such agencies as AEC, National Science Foundation, National Aeronautics and Space Agency, and the National Bureau of Standards under a Secretary of Science is the object of renewed efforts, backed by legislation proposed by Senators Humphrey (Minn.) and McClellan (Ark.).

J. L. Gillman, Jr.

Contractor named for United Engineering Center

General contractor for the projected 18-story metal, glass, and limestone United Engineering Center to go up on United Nations Plaza in New York City will be Turner Construction of New York . . . Latest figures in the Member Gift Campaign show A.I.Ch.E. subscriptions at more than $275,000—better than 90 percent of the quota . . . More than $6 million has been subscribed of the entire campaign total of $10 million.

Standard Oil (Ohio), Atlas Powder, form joint company

Solar Nitrogen Chemicals, jointly owned in equal proportions by Standard of Ohio and Atlas Powder, will take over the Lima, Ohio, ammonia and petrochemical facilities of Sohio Chemical, wholly-owned Standard Oil subsidiary. Sohio will continue to operate the plant and to act as sales agent for the new company.

SCOPE

L.A. Refineries harness pollutants—Smog continues

At expenditure of some $33 million by oil refineries in Los Angeles County during the last ten years, contaminant output from refineries in the area has been reduced to about 300 tons per day, according to the final report on a 30-month study by a joint group representing the U.S. Public Health Service, the California State Dept. of Public Health, and the L.A. County Air Pollution Control District. Approximately 1,700 tons per day are presently being controlled by devices and remedies now in effect, says the survey report. Investigated by survey teams were 16 types of equipment and operations in 18 refineries with a total crude oil capacity of 734,000 barrels per day. According to a recent statement by the Air Pollution Foundation, there is nothing that the refineries or any other industries of the Los Angeles area can do that they have not already done to reduce the eye-irritating, ozone-forming smog.

Hydrocarbons and oxides of nitrogen, in the opinion of the survey compilers, are the contaminants most responsible for smog formation in the area: less-important culprits also inventoried were sulfur dioxide, sulfur trioxide, ammonia, particulate matter, aldehydes, and organic acids.

Undue optimism is not justified, however, the survey report hastens to add. Refineries are estimated to account for only 7% of all hydrocarbons and 8% of all oxides of nitrogen emitted daily into the Los Angeles atmosphere. Approximately 70% of this sort of contamination in the County is believed attributable to motor vehicle exhausts. While several devices for control of auto exhausts are under active testing (see CEP, February, Scope, page 17), none are believed ready for widespread adoption, during the next two or three years, at least. A certain amount of reduction in sulfur dioxide pollution can be expected, says the report, when Rule 62, limiting refineries and steam power plants to the use of natural gas instead of fuel oil during the "smog season" goes into effect May 1, 1959.

Also on the L.A. smog front—"No correlations were found between eye irritation and aerosol, or eye irritation and ozone," says a recent report from the Air Pollution Foundation, which goes on to remark that "severe eye irritation was frequently formed in the absence of either aerosol or ozone." According to the Foundation, foggy smog, like sunshiny smog, results from irradiation of automobile exhaust—not from "sulfuric acid mist" or other causes.

Industry work elsewhere

Pollution abatement progress over a wide gamut of chemical processing and allied industries were reported at a recent Cincinnati meeting of the National Technical Task Committee for Industrial Wastes. The Committee was created in 1950 by the Surgeon General of the U.S. Public Health Service. It serves as an industry forum on waste problems and as an advisory group to PHS. Highlights of the accomplishments for '58 were:

A forward surge in in-plant systems for pollution reduction, considerable progress in new waste treatment plant construction;

More consideration to aerobic methods of treatment, with special emphasis on activated sludge for handling of organic wastes. Important data is also being developed on oxygen transfer rates through the use of turbo aerators;

In the electroplating industry, a number of "semi-closed cycle" treatment systems have been installed; in particular, chrome wastes and cyanide wastes are being treated for recovery of water and chemicals.

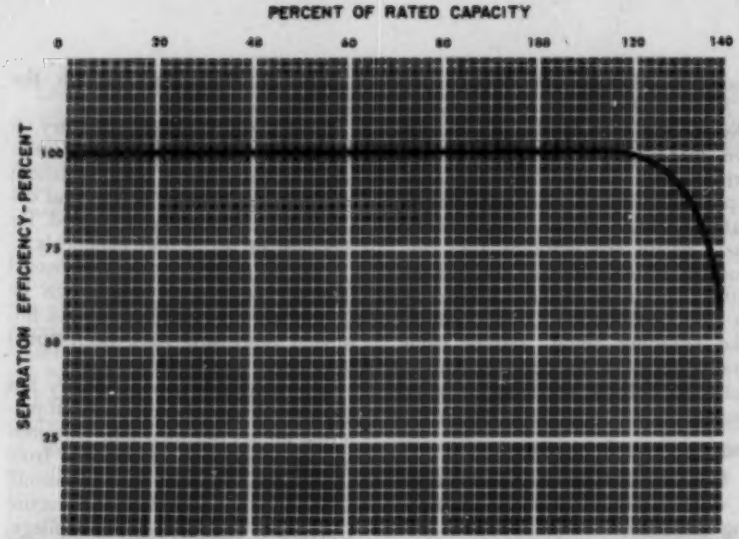
Use of settling basins, increased recovery of solvents which can be re-used through distillation, and improved processing have been noted throughout the paint industry.

The pulp and paper industry has been the scene of intensive anti-pollution efforts during 1958. Dewatering and disposal of sludges from clarification of pulp and papermill effluents is being studied at Syracuse University and Kalamazoo College, and in a number of mill development projects. Stream reaeration by turbine regeneration and high-efficiency sparging is under investigation by the Wisconsin Sulfite Pulp Manufacturers' League and by the Council at the University of Maine. Progress in removal of suspended solids from wood-room effluent continues with the installation of several new types of screening devices at individual mills. Lignin utilization is increasing as new uses for products made from spent pulp cooking liquor solids are being found. Biological oxidation for BOD removal is gaining acceptance, three full-scale plants are under consideration.

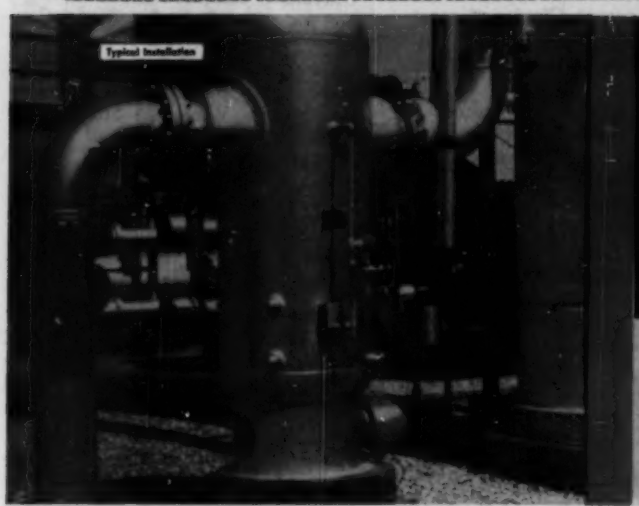
Second U. S. Polypropylene Producer

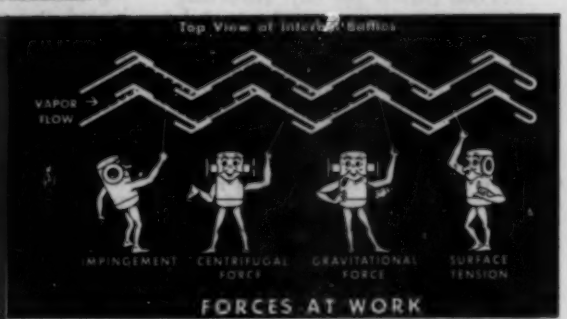
Using a Sun Oil-developed process and new fiber and film manufacturing techniques worked out by researchers at American Viscose, AviSun, an equally-owned affiliate, is scheduled to be the nation's second (and largest) supplier of polypropylene by mid-1959. Proposed capacity is 20 million pounds per year, facilities have been leased at the Port Reading, N.J. linear polyethylene plant of Koppers Co. . . . Meanwhile, Montecatini, of Milan, Italy, who have claimed what amounts to a world-wide patent position on polypropylene (CEP, Scope, December, 1958, p. 19), have licensed two French producers, Pechiney and La Societe Normande de Matieres Plastiques, to erect two plants in France, each with a capacity of 22 million pounds. Both French plants are slated to go on stream in 1960.

FLAT EFFICIENCY CURVE with PEERLESS Separators...



with Peerless Separators you can remove entrained liquids from process vapor lines and maintain a high efficiency over the entire range of flow.





FORCES AT WORK

The above illustration shows a top view looking down at two of the many internal separator baffles. Entrained liquid droplets are caught in the pockets and drained down out of the gas flow . . . thereby completely stripping the gas before it leaves the mist extractor.

PEERLESS MFG. CO. DALLAS TEXAS

PEERLESS MANUFACTURING COMPANY

P.O. Box 13165 Dallas, Texas

Representatives in All Principal Cities

OTHER OUTSTANDING FEATURES OF PEERLESS SEPARATORS

- **Low pressure drop across mist extractor — less than 6" of water.**
- **Compact and economical.**
- **Vane units can be made easily removable.**
- **Mist extractor and vessel can be made of any type material. Carbon steel mist extractors can be placed in a vessel and stress relieved without damage.**
- **Can be designed for any capacity or special requirement.**

OVER 20,000 SEPARATORS and SCRUBBERS IN SERVICE

For more information, turn to Data Service card, circle No. 61

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U.S.I. CHEMICAL NEWS

Mar. ★ A Series for Chemists and Executives of the Solvents and Chemical Consuming Industries ★ 1959

World's Largest Industry-Owned Research Reactor Opens at Plainsboro, N. J.

U.S.I. One of Ten Participants

On January 19, Industrial Research Laboratories, Inc. (I.R.L.) -- the world's largest nuclear reactor financed entirely by private funds and devoted solely to industrial research -- made its formal bow at Plainsboro, N. J. U.S.I. and nine other companies are participating in the venture, using the reactor as a tool for basic and applied studies in many fields.

The fields of interest of the participants include alcohol, chemicals, special metals, plastics, tobacco, machine tools, explosives, packaging, glass, lead, electronics, oil and rubber. This wide range of interests will make I.R.L. a major contributor to the "Atoms for Peace" program.

The five-million-watt "swimming pool" type reactor is housed in an 87-foot-high, aluminum-sheathed "beehive" of reinforced concrete. It

MORE

Methionine Bibliography Now Available from U.S.I.

Readers of the November U.S.I. Chemical News have expressed tremendous interest in the lead story on methionine absorption through the skin. Hundreds of letters, telegrams and phone calls have been received asking for more complete information. To answer these many requests, we have prepared a selected bibliography of published articles on the oral and topical applications of methionine, which should prove very helpful to interested parties.

This bibliography is now available on request.

Have You a New Product To Tell the World About?

Make it routine to send your publicity releases on new products and developments to the Editor of U.S.I. Chemical News, often called the "Front Page of the Chemical Process Industries." The issue you are reading right now will be printed in over 250,000 copies of the leading publications serving the chemical and related fields. The Technical Developments column alone will probably produce over 600 inquiries, judging from the past average. You incur no charges or obligations by sending us your new product releases. The material will be judged and used solely on the basis of newsworthiness and space limitations. And of course we cannot guarantee that your item will definitely appear because of these considerations.

U.S.I. Reopens Second Chlorine-Caustic Unit At Huntsville, Alabama

Plant Ideally Located to Supply Growing Needs of Southern Textile and Pulp and Paper Industries

U.S.I. increased chlorine and caustic soda output at Huntsville, Alabama recently, when a second unit was put back into operation. U.S.I. has been producing at this location since 1952. The Huntsville plant site offers the benefits of economic freight rates to a large number of users, and is therefore an ideal location from which to supply the chlor-alkali requirements of Southern textile and pulp and paper operations.

Liquid chlorine is available to users in 30-ton and 55-ton tankcars. The future possibility of barge shipments is being studied. Commercial grade, 50% liquid caustic soda is available in 8,000- and 10,000-gallon insulated and lined tankcars as well as in barges.

Both chlorine and caustic soda -- products of the electrolytic decomposition of brine -- are among the top dozen industrial inorganic chemicals produced in the United States today, in terms of tonnage. In 1957, the most recent year for which U.S. Department of Commerce figures have been reported, 3.9 million short tons of chlorine were marketed, and 4.0 million short tons of caustic soda, on a 100% NaOH basis, were sold.

MORE

Colognes Estimated Sixth In Aerosol Sales in 1958

Early estimates indicate that aerosol cologne sales for 1958 stand at over 26 million units. This would be an increase of about 50% over the 1957 sales figure of 18 million units. U.S.I. reports that the rise in its sales of anhydrous alcohol from 1957 to 1958 for aerosol cologne applications supports this estimate. Industry spokesmen reveal that 1958 was the first year in which aerosols accounted for over half the cologne market, in terms of dollar volume.

In 1958, as in 1957, colognes will probably rank sixth in unit sales among aerosol products, when all figures have been tabulated. The 1958 sales volume ranking should look much as it did in 1957, with hair sprays, shaving lathers, room deodorants, insect sprays and coatings taking the first five places.

Cell room of chlorine-caustic soda unit, U.S.I. plant, Huntsville, Alabama.

Mar. ★ **U.S.I. CHEMICAL NEWS** ★ 1959

CONTINUED

Chlorine & Caustic

Chlorine End-Use Pattern by Industry

INDUSTRY	PERCENT OF TOTAL
Pulp and Paper	15.0
Chlorinated Solvents	13.0
Automotive Fluids	11.0
Plastics and Resins	11.0
Insecticides and Herbicides	7.5
Refrigerants and Propellants	5.0
Water and Sewage	3.5
All Others	34.0
TOTAL	100.0

Caustic Soda End-Use Pattern (Estimated)

END-USE	PERCENT OF TOTAL
Chemicals	26.9
Rayon and Film	17.8
Pulp and Paper	6.6
Export	5.8
Petroleum Refining	5.5
Lye and Cleansers	4.1
Textiles	3.5
Soap	2.1
All Others	27.7
TOTAL	100.0

Organic Derivative of Hypochlorous Acid Being Tested in Cancer Surgery

Surgeons are testing an organic derivative of hypochlorous acid — a form of monoxychlorosene — as a wash for cleaning cancer wounds after operating. Used in this manner, the material has been successful in halting the growth of cancer cell seedings in rats after cancers had been removed surgically. The chemical is not a cancer cure however.

The material is being employed widely in cancer operations on humans at the present time. Thus far the usual post-operative tests via supravital staining techniques reveal that all cancer cell seedings remaining in and around the wounds are destroyed by the wash.

The hypochlorous acid raw material for this compound is unstable and not available commercially. It must be prepared by the reaction of chlorine with water.

CONTINUED

Reactor

is producing its chain reaction under 37 feet of demineralized water which serves as moderator, coolant and shield. The unit provides a source of neutrons, gamma rays and radioactive isotopes for study.

A permanent staff of 30-40 scientists and technicians is operating the reactor. In addition, participating companies maintain permanent staffs in individual research laboratories.

U.S.I. Studying Processes, Products

U.S.I.'s participation in this new undertaking is one more step in its expanding research program. Basically, its investigation will cover nuclear radiation for initiating or modifying chemical reactions, for controlling production processes, and for developing and testing new products.

Technicians load core of new I.R.I. nuclear reactor with fuel elements preparatory to start of operation. Core is 37 feet below surface of water which acts as coolant, shield.

TECHNICAL DEVELOPMENTS

Information about manufacturers of these items may be obtained by writing U.S.I.

Sodium and potassium borohydride information is presented in 34-page manual now available. Properties, reactions, handling are discussed. Thirteen tables cover technical data collected from other published works. **No. 1450**

The 1958 edition of "Annual Review of Biochemistry" can now be purchased. It is a 775-page volume, containing 22 sections by different authors, covering developments in all biochemical fields. **No. 1451**

Heat transfer coefficients in small sodium heat exchangers are discussed in a reprint now available. Empirical equations are developed for calculating the over-all heat transfer coefficients for tube and annulus exchangers. **No. 1452**

Molybdenum hexacarbonyl is now available commercially for use as a chemical intermediate, catalyst and vapor phase deposition raw material. Compound and derivatives are under study for dyes, toners, lube additives, etc. **No. 1453**

Rotating-cylinder viscometer, designed for measurement of liquids at very low shear stresses, is now on market. Claimed to be particularly useful for accurate studies of high-molecular-weight polymers. **No. 1454**

New aluminum soap has been developed to gel solvents without use of heat. Bulletin now offered on product tells how to form stable gels from non-polar solvents and mixes of polar and non-polar solvents. **No. 1455**

Automatic, lab-bench zone refiner just developed will give high-purity organic reagents from run-of-bottle chemicals. Said to purify any material with 50-300°C M.P. Greatest use seen for organics hard to refine by usual means. **No. 1456**

Butene-1 can now be obtained with liquid vol. analysis of 98.5% butene-1, 0.0% isobutylene and butadiene, 0.8% n-butane, 0.7% butene-2. Butene-2 now obtainable with 95.0% butene-2, 0.5% butene-1, 1.0% butadiene, 3.5% n-butane. **No. 1457**

Standard fuel elements in 4 types, for use in low-power research reactors, now on market. Availability of standard elements claimed to greatly reduce costs of custom design, special tooling and set-up, special engineering. **No. 1458**

Methyl borate is now available commercially in carload quantity. Material is a widely-miscible, non-aqueous solvent, azeotroping agent, Lewis-acid catalyst and intermediate. Also acts as a neutron absorber and detector. **No. 1459**

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Ammonium Nitrate, Nitric Acid, Nitrogen Fertilizer Solutions

Phosphatic Fertilizer Solutions: wet process phosphoric acid.

Sulfuric Acid: all strengths, 60 Baume to 40% Oleum. Also Electrolytic grade to Federal specifications. Tank cars or tank wagons.

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Progress Report...

And now, polyurethane lacquers

Polyurethane lacquers are creating great interest in the surface coatings industry. A properly formulated lacquer produces a coating that is hard and tough . . . and has excellent resistance to abrasion, corrosion, and weathering. These coatings can be applied by spray or brush and have potential value in almost every consumer and industrial application.

A critical problem in formulating urethane lacquers is the quality of the solvents used. If the urethane reacts with acid or water in the solvent system, carbon dioxide may be formed ...thus creating bubbles in the coating.

To meet the high purity solvent requirements for urethane lacquers, CARBIDE is marketing two new acetate solvents—CELLOSOLVE Acetate, 99% (Polyurethane Grade), and Ethyl Acetate, 99.5% (Polyurethane Grade). Water content is kept below 0.05% by weight and free ethanol does not exceed 0.01% by weight. Thus, reactive hydrogen is kept to a minimum.

Here are the complete specifications that must be met before CELLOSOLVE Acetate, 99% and Ethyl Acetate, 99.5% are shipped to you.

	CELLOSOLVE Acetate, 99% *	Ethyl Acetate, 99.5% *
Purity, % by wt., min.	99.0	99.5
Acidity (as acetic), % by wt., max.	0.02	0.0005
Water, % by wt., max.	0.05	0.05
Free Ethanol, by diff., % by wt., max.	None	0.01
Nonvolatile matter, % by wt., max.	None	0.01
Color, Pt-Co, max.	15	10
Distillation, 760 mm Hg		
1 bp, min.	150.0° C.	75.5° C.
Dp, max.	160.0° C.	78.0° C.
Odor	Mild	Esteric, fruity and non-residual

*Polyurethane Grade

For further information, check the coupon for CARBIDE's technical information bulletin on Urethane Solvents.

Reminder to drug makers

Numerous pharmaceutical products can be synthesized from alkylene amines. Solutions of aminophylline, a salt used for treating cardiac ailments, can be prepared from ethylene diamine with theophylline. The ethylene diamine also serves to stabilize the solution.

Antihistamines and imidazoline derivatives, used for treatment of circulatory disturbances, can be obtained by using ethylene diamine and substituted ethylene diamines as starting materials. Many other types of pharmacologically active agents can be prepared from alkylene amines. More information on these useful CARBIDE chemicals can be found in a new booklet, available now. Check the coupon for your copy.

Gas dehydrating with glycols

Natural gas produced from most wells contains water. Both the liquid phase and the water vapor must be removed in order to prevent the formation of hydrocarbon hydrates which would block gas transmission lines. The easiest and most common way to do this is by passing the gas through a glycol solution.

Both diethylene and triethylene glycols are used to remove moisture from natural gas before it enters the pipeline. Triethylene glycol is also used as a liquid desiccant in small packaged plants at the gas well head to eliminate the need for alcohol injection or line heaters in field gathering systems.

Dehydration units using diethylene glycol and triethylene glycol have the advantages of low investment cost and simplicity of operation. A further advantage is that glycols are not corrosive to the carbon steel used in gas field equipment. Thus, most glycol units operate without trouble year in and year out.

CARBIDE maintains an extensive engineering service group to help natural gas producers get the best possible gas dehydration efficiency with CARBIDE's diethylene glycol and triethylene glycol. As a part of this service, a comprehensive bibliography of articles devoted to improving gas dehydration operations is available. Compiled by CARBIDE, this publication lists every major article on gas dehydration since 1931. To obtain a copy, check the coupon for Technical Information Bulletin F-9289.

Tear out this coupon. Check the boxes on which you'd like more information, and mail to Dept. H, Union Carbide Chemicals Company, 30 East 42nd Street, New York 17, N. Y.

☐ Urethane Solvents. ☐ Alkylene Amines.
☐ Bulletin F-9289 (Gas Dehydration).

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And remember, there is a CARBIDE sales office near you where you can obtain the services of a CARBIDE Technical Representative. His wide industry experience is backed both by extensive chemical training and by Technical Specialists.

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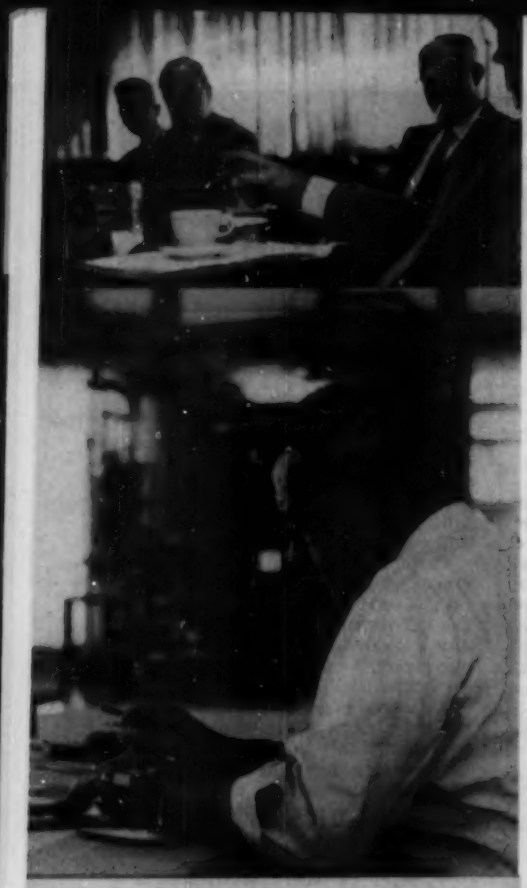

When you consider expansion... the most important investment you can make is in the creative ability of men.

FLUOR

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Design in three dimensions

At Fluor's Los Angeles headquarters, there is an 8,000-square-foot building where 30 plant designers work with 20 professional modelmakers. Drafting tables are within 10 feet of model assembly tables. Another building contains an elaborate photographic studio where precisely scaled isometric and plan views can be taken under shadowless lighting.

All this began seven years ago when Fluor engineers built a scale model and rigged miniature hoists to solve a difficult erection problem. Success of this trial led to experiments with the use of models as a basic design tool. Cost studies showed substantial savings in drafting man-hours (net savings, above modelmaking costs.)

Today, models are to be found in most of Fluor's drafting rooms, and nearly all Fluor-built plants are designed with the aid of this tool. Beyond the dollar savings there are many less tangible benefits. Sizable groups can confer over a model, reach quick agreement on layouts, approve or revise many details at a single session.

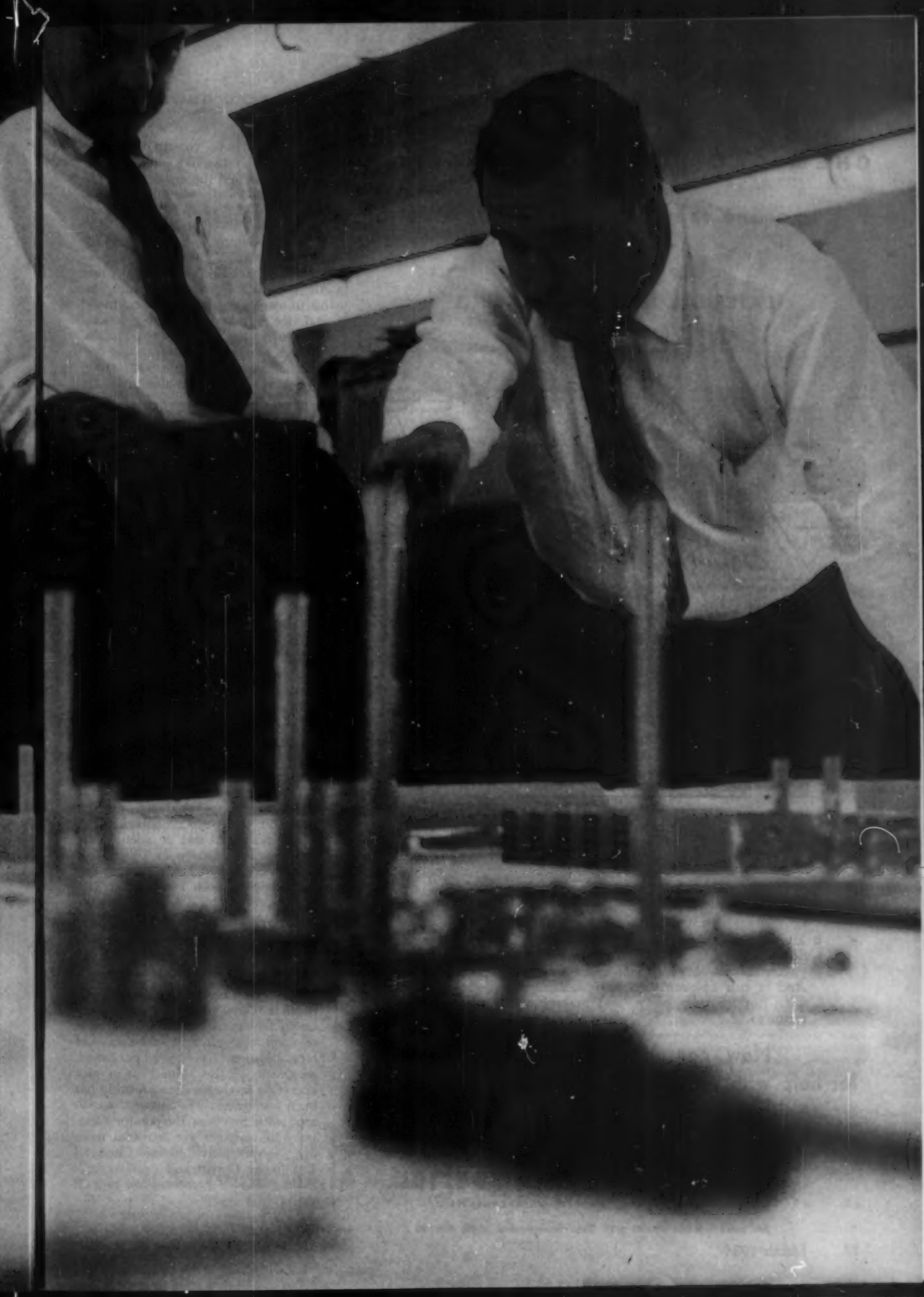
Piping runs are shorter and more direct, valves and instruments are more accessible when designers lay them out on a model (a Fluor comparison study of a refinery design showed a $50,000 saving in pipe, fittings and fabrication by use of a model vs. conventional layout drawings.)

Costly revisions are minimized when many specialists can study a complete plant in miniature before construction begins. In the field, models serve as a reference for construction crews and a guide for operator training.

Unless scale models are properly used—as a basic, integrated design tool—most of these advantages are lost. The development and refinement by Fluor of design techniques using scale models has been a creative contribution to the engineering and construction industry.

For more information on the use of scale models in design and construction, write to Dept. 31, The Fluor Corporation, Ltd., 2500 South Atlantic Boulevard, Los Angeles 22, California.

For more information, circle No. 26



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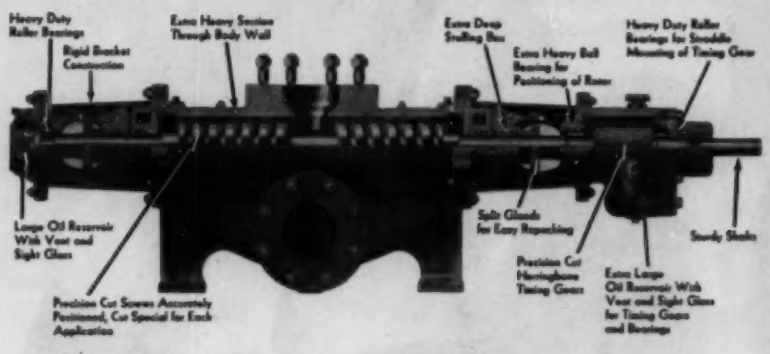
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- This highly adaptable Warren External Gear and Bearing Screw Pump, available in an almost endless number of patterns, can solve special space or piping problems too. And it can be furnished with heating or cooling jackets, with hopper type body, and in any metal your problem requires.

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about our authors

W. L. Faith, who contributes a report on the National Conference on Air Pollution and the article *(Air Pollution Abatement)* to this month's issue, has done considerable work in the field. He is author of a book "Air Pollution Control", in addition to several papers on the subject, and is currently managing director of the Air Pollution Foundation. Faith, in his former capacity as chief engineer and vice president of the Foundation, supervised the various air pollution research projects undertaken by the Foundation scientists and contracting laboratories throughout the nation.

(l. to r.) Authors Newman, Bennett Faith

Henry R. Linden, who along with **J. M. Reid,** authored the article *(Ethylene Process Variables)* holds several patents in the fields of gasification, gas utilization, petrochemicals and petroleum processing. He has, in addition, published papers and bulletins on the topic. Linden is research director of the Institute of Gas Technology.

Fred A. Hartley *(Shale Oil — How Soon?)* has directed the Union Oil Company's oil shale research and development program since its inception in 1955. In that year he spent several weeks in Europe studying, at first hand, oil shale experiments in Germany, Scotland and Sweden. Vice president for research at Union Oil, Hartley heads a 500 man team at the company's research center near Los Angeles.

Mark D. Hollis *(Environmental Changes and Water Pollution)* is assistant Surgeon General and Chief Engineer, U.S. Public Health Service.

H. H. Newman and **Richard C. Bennett** *(Circulating Magma Crystallizers)* feel that while much information on the physical chemistry of crystallization has been published, treatment of the subject as a unit operation in chemical engineering has been insufficient. The men are associated with Swenson Evaporator Company as manager and assistant manager, respectively, of the Chemical Equipment Department.

continued on page 28

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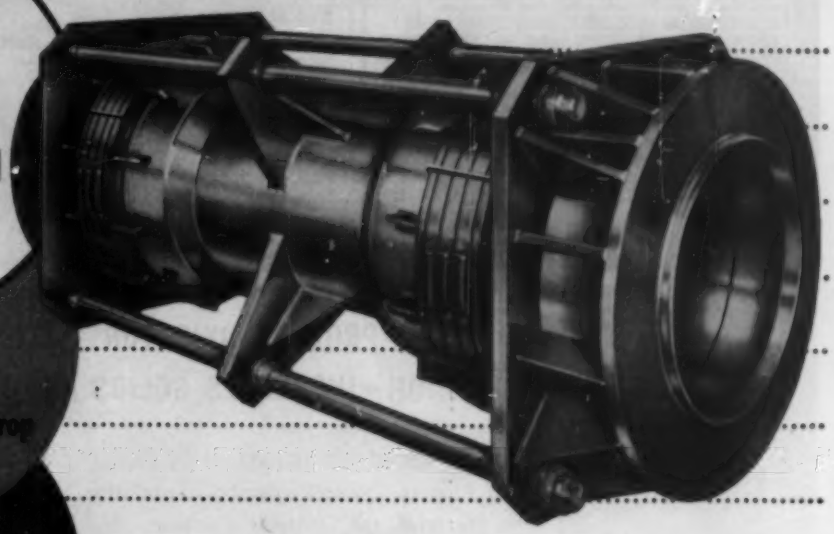

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PACKLESS EXPANSION JOINTS

Adsco CORRUFLEX Expansion Joints are manufactured in sizes of 3" or larger, designed for specific line conditions. These units provide maintenance-free, trouble-free service.

Every possible combination of pipe motion can be fully compensated for – absorption of axial motion, lateral deflection and angular rotation – with one or more standard or custom-engineered CORRUFLEX packless joints built by Adsco.

For complete engineering data write for your copy of the new CORRUFLEX Expansion Joint Bulletin, No. EJ-59-50 on your company letterhead.

Designed for a 30" diameter high pressure, high temperature service line in a southwestern aircraft and missiles engine test center, the Adsco CORRUFLEX Self-equalizing stainless steel Expansion Joint shown above is one of many custom-designed units in service.

ADSCO Piston-ring Slip-type Expansion Joints are world renowned as the only joints which can be unpacked and completely repacked without shutting down line pressure. As the only manufacturer of both slip and packless expansion joints, Adsco recommends the proper type which is best suited to the demands of the job – your assurance of complete satisfaction, utmost economy.

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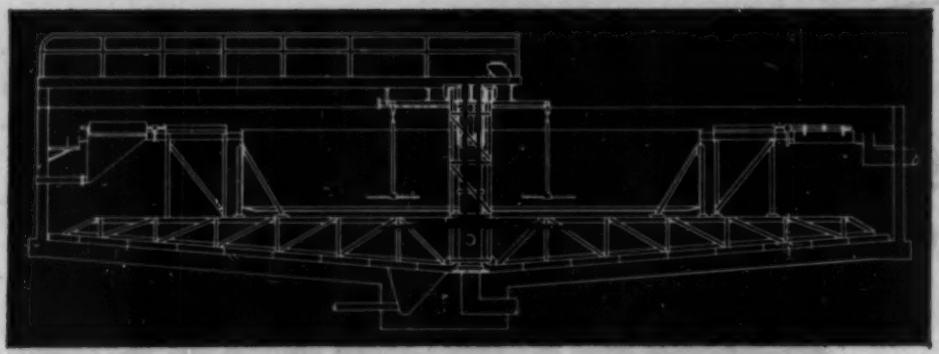

Internal sludge recirculators, Non-Clog Diffusers and a sludge thickening deflector are exclusive features of the Type CA Oxidator.

EIMCO-PROCESS OXIDATOR®—WITH CONTROLLED INTERNAL SLUDGE RECIRCULATION—INCREASES SOLIDS AND BOD REMOVALS

The complete line of Eimco-Process Oxidators, Clarifiers and other sedimentation equipment is described in our new Bulletin SM-1005. We will be happy to send you a copy on request.

Developed and introduced by Eimco-Process, and with a number of exclusive features, the Oxidator combines aeration, flocculation and sedimentation in a single circular tank. When aeration and flocculation of the solids are provided prior to clarification, many finely divided and colloidal solids that could not be removed by conventional sedimentation are flocculated and collected with the sludge. The aeration keeps the influent fresh and, combined with controlled internal sludge recirculation, gives increased floccule size, minimizes scum formation, and gives increased suspended solids and BOD removals.

In this unique design, internal sludge recirculation is accomplished through airlifts with intakes below the special sludge pocket protection deflector. By placing the intakes in this protected heavy sludge zone and controlling each lift with a separate valve, optimum recirculation rates can be obtained.

Gentle or intense aeration, adjustable sludge recirculation rates and controlled sludge thickening make the Oxidator the most flexible of all sedimentation equipment. Used alone, it can provide economical intermediate treatment; used with secondary equipment, it can substantially reduce total plant investment.

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. . . another outstanding installation

Two 75 ft. dia. Type CA Oxidators, Puyallup, Washington. Consulting Engineers—Gray and Osborne, Yakima, Wash.

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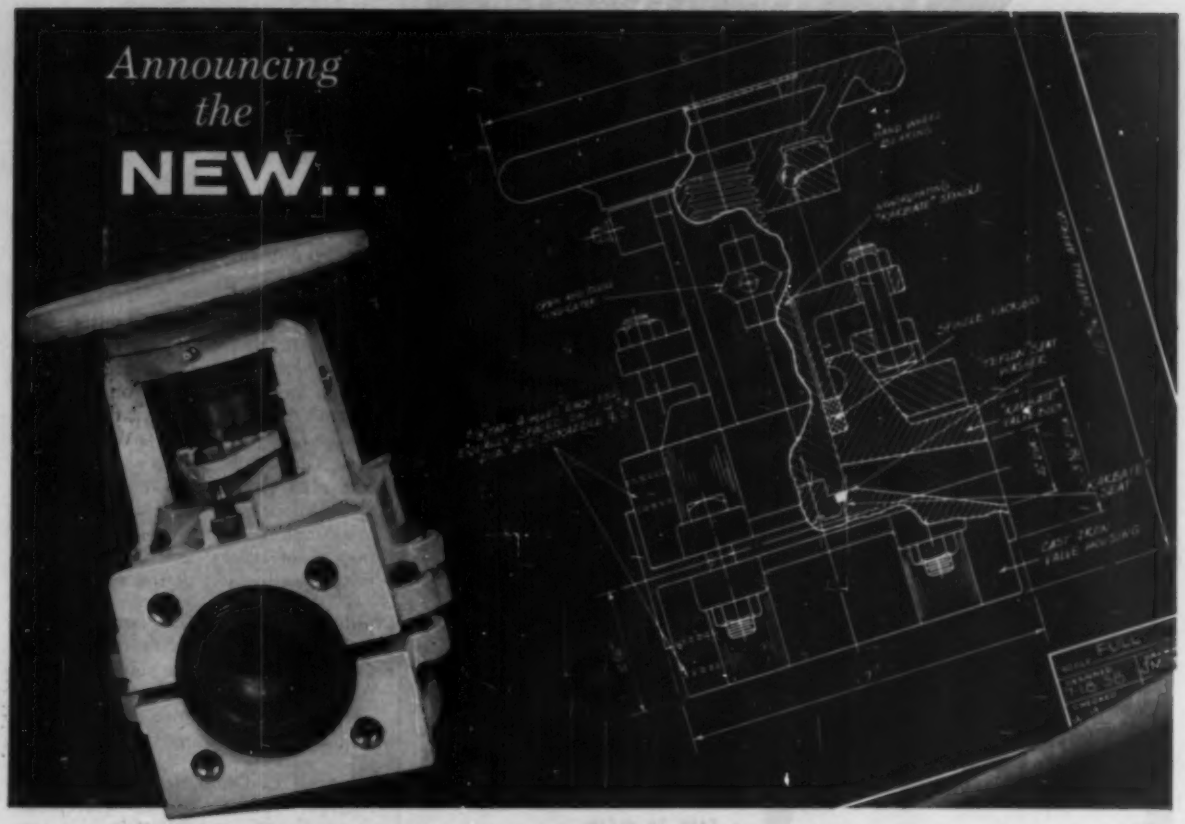

"KARBATE" GLOBE VALVE TYPE G

National Carbon Company announces the availability of a completely new "Karbate" impervious graphite globe valve. The many new design features of this valve were performance tested for approximately 1 year prior to adoption.

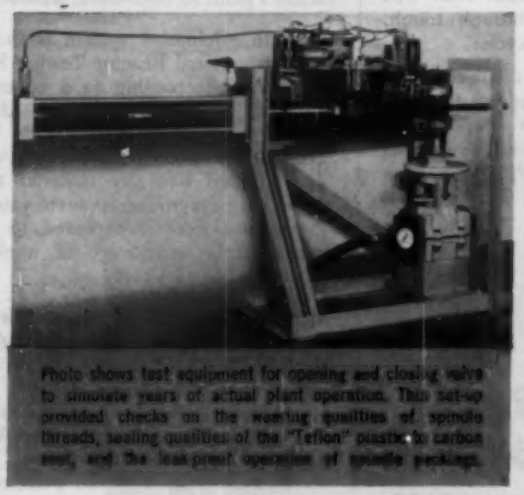

Photo shows test equipment for opening and closing valve to simulate years of actual plant operation. This set-up provided checks on the wearing qualities of spindle threads, sealing qualities of the "Teflon" plastic to carbon seat, and the leak-proof operation of spindle packings.

Principal design features:

- **"Teflon" plastic to carbon seat**—provides positive seal when valve is closed.
- **Metal handwheel to "Karbate" spindle thread design** — provides long operational life — no binding because of corrosion.
- **Non-rotating spindle**—simplifies spindle packing problem. Provides leak-tight seal using a variety of packings such as asbestos impregnated with "Teflon" plastic, braided "Teflon" plastic, asbestos impregnated with graphite and elastomers.
- **Lubricated ball-bearing handwheel to yoke arrangement**—provides easy movement of handwheel with positive lock to yoke.
- **Armored design**—prevents outside shock damage.
- **Positive indication of open and closed positions.**
- **Valve can be adapted to motor operation.**
- **Almost universal corrosion resistance**—can be used in a wide variety of corrosive chemicals. All wetted parts are "Karbate" impervious graphite or "Teflon" plastic.

Presently, this valve is available in the two inch size. One inch, one and one-half inch, three inch and four inch valves will be added to the line in the future.

"National", "Karbate" and "Union Carbide" are registered trade-marks of Union Carbide Corporation

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FOR TOUGH FILTERING *Use* NEWARK STAINLESS STEEL FILTER CLOTH

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- EXCEPTIONALLY LONG SERVICE LIFE

Check these *operating* advantages found in Newark Stainless Steel Filter Cloth. They may suggest the solution to one of your special filtering problems or they may be the answer to your need for a backing cloth that will really stand up through tough, corrosive filtering cycles.

Newark Stainless Steel Filter Cloth is easily adapted to practically all types of filters and is available in a wide variety of weaves. When writing please give us details on your process.

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about our authors

from page 24

(l. to r.) Authors Linden, Hartley, Brady

The work of **L. N. Johanson** and **Kermit B. Bengtson** *(High Temperature Chlorination in a Fluidized Bed)* results from an interest on the part of both men in the local deposits of olivine in the Seattle, Washington, area, where Johanson is associate professor in the Chemical Engineering Department at the University of Washington. Bengtson has, over a period of years, continued studies toward utilization of the mineral.

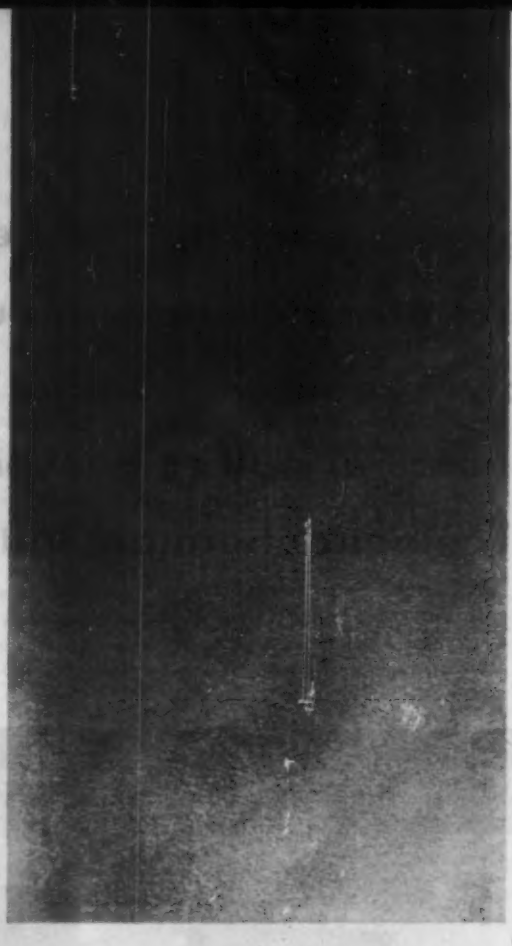
Sidney O. Brady *(In-Plant Pollution Control)* has been with the Humble Oil Refining Company since 1937. He is currently Senior Research Engineer, working on prevention of air and water contamination.

Wendell E. Dunn, Jr. *(Olivine Chlorination—An Alternative Interpretation)* contributes his article as a supplement to the work of Johanson and Bengtson on the subject. He is with Du Pont Research Division.

Manufacture of new bacterial and fungicidal formulations (containing tributyltin oxide and other organotin chemicals) by Metal & Thermit Corp. for Permachem, will take place at the former's plant in Carrollton, Kentucky.

A waste calcination system is to be built at National Reactor Testing Station, Idaho, according to a contract awarded The Fluor Corp. by AEC. Radioactive liquids produced in the recovery of fissionable materials will be processed into dry material and stored in underground concrete vaults. The new system is expected to increase safety in storage of nuclear wastes.

A.I.Ch.E. visitors to the International Petroleum exposition in Tulsa, May 14-23, can register and get information about other members attending the show, at a special Center set up for that purpose. The IPE Technical Societies' Registration Center will be located in the Petroleum Engineer Publishing Company exhibit on the exposition grounds.



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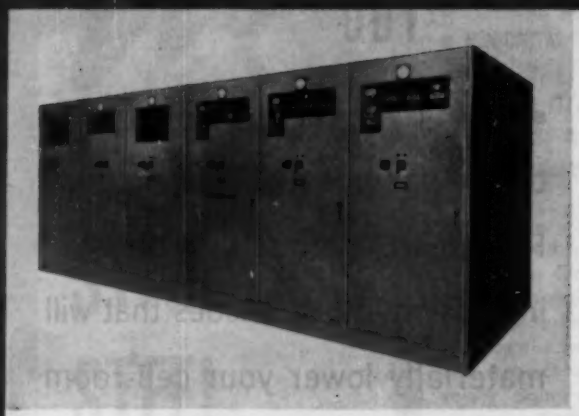
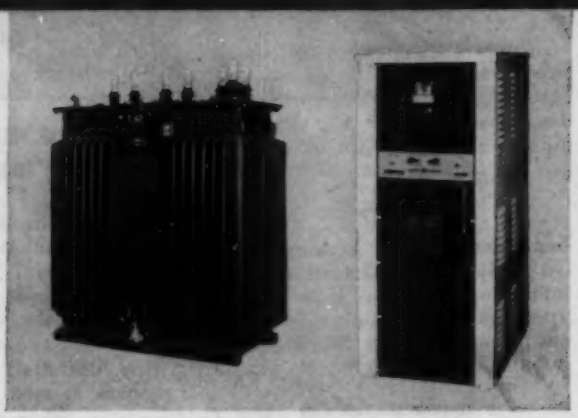
Designed to provide up to 96% efficiency, General Electric semiconductor power rectifier systems offer reliable, economical power conversion for the electrochemical industry

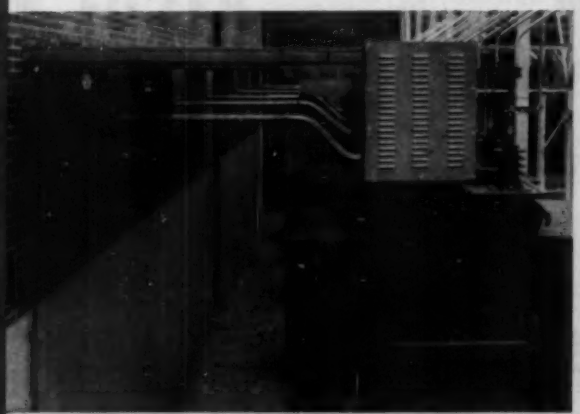
Typical General Electric Rectification System:



1 **SYSTEM COORDINATED** General Electric metal-clad switchgear equipment handles normal switching functions and provides dependable a-c short-circuit protection.



2 **LIQUID IMMERSED** (l.) or dry-type (r.) Inductrol® voltage regulators compensate for system regulation and a-c supply variations to provide d-c control at desired voltage levels.



4 **SYSTEM INTEGRATED BUSWAY**—an interleaved 3-phase design completes connection to rectifier. Busway provides greater flexibility . . . reduced installation costs.

5 **COMPACT, EFFICIENT** rectifier sections convert alternating current to direct current for process requirements. D-c current transformers, mounted on d-c buses, measure output.

In the last few years, General Electric has supplied semiconductor power rectifier systems for over 85 electrochemical installations. Users report that these systems—designed to provide over 90% efficiency above 15 volts d-c, and from 94 to 96% efficiency above 60 volts d-c—have increased system reliability and reduced installation and operating costs.

Coordinated System Components Provide Peak Performance, Longer Life—Because each electrochemical facility requires special d-c voltages for its particular process needs, power rectifier systems should be tailored to each installation for maximum reliability and economy. For this reason, General Electric manufactures all major power rectifier system components—including air-cooled and water-cooled, germanium and silicon rectifiers—and is fully equipped to provide installation and service assistance on all components.

G-E Semiconductor Power Conversion Systems Find Wide Application—Due to their greater efficiency and economy, General Electric rectifier systems have enjoyed widespread acceptance as d-c power sources in hydrogen, chlorine and fluorine plants; copper refining, aluminum reduction, tin-plating, chrome-plating and aluminum anodizing processes; and for powering d-c motors. New uses for these versatile dependable power conversion systems are continually being developed.

For Complete Information on General Electric *system-engineered* and *performance-proven* semiconductor power rectifier systems, contact your nearby General Electric Apparatus Sales Office. Your G-E sales representative can help specify semiconductor power rectifier equipment specifically tailored to your process needs.

Write G-E Co., Section 686-1, Schenectady 5, New York, for These Free Bulletins: GEA-6684, Semiconductor Rectifier Power Conversion Systems for Electrolytic Processes; GEA-6375A, Semiconductor Power Rectifiers.

Engineered Electrical Systems for the Electrochemical Industry

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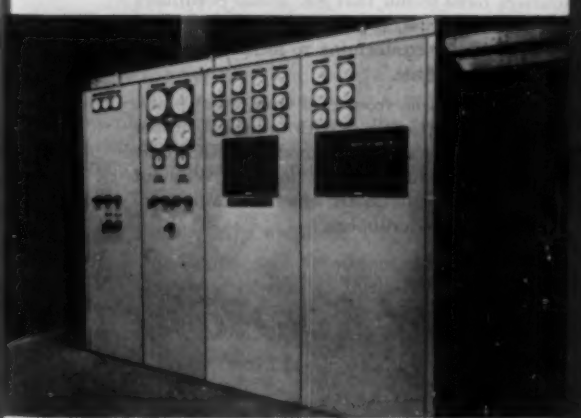
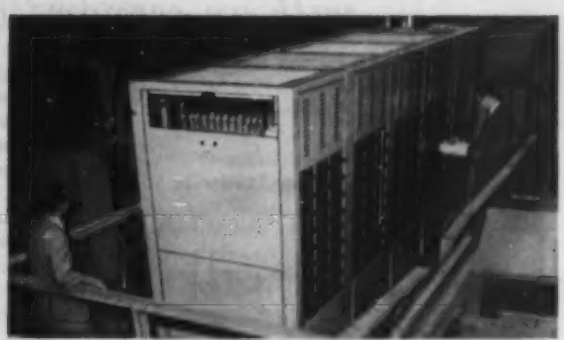
3 **G-E RECTIFIER TRANSFORMER** gives proper ratio of a-c primary to desired conversion voltage . . . can be located out-of-doors.

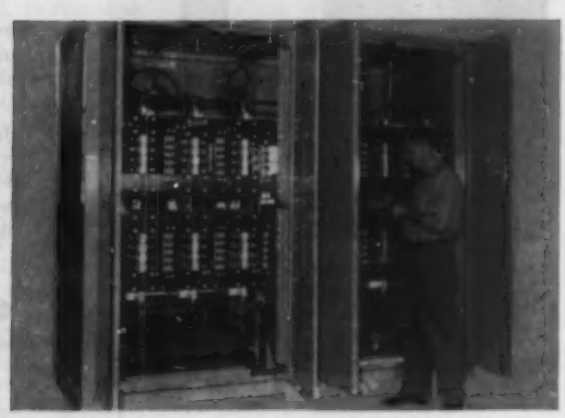


6 **MASTER DUPLEX CONTROL PANEL** provides centralized instrumentation and control of complete G-E power conversion system.

General Electric Offers Both Air and Water-cooled Rectifiers

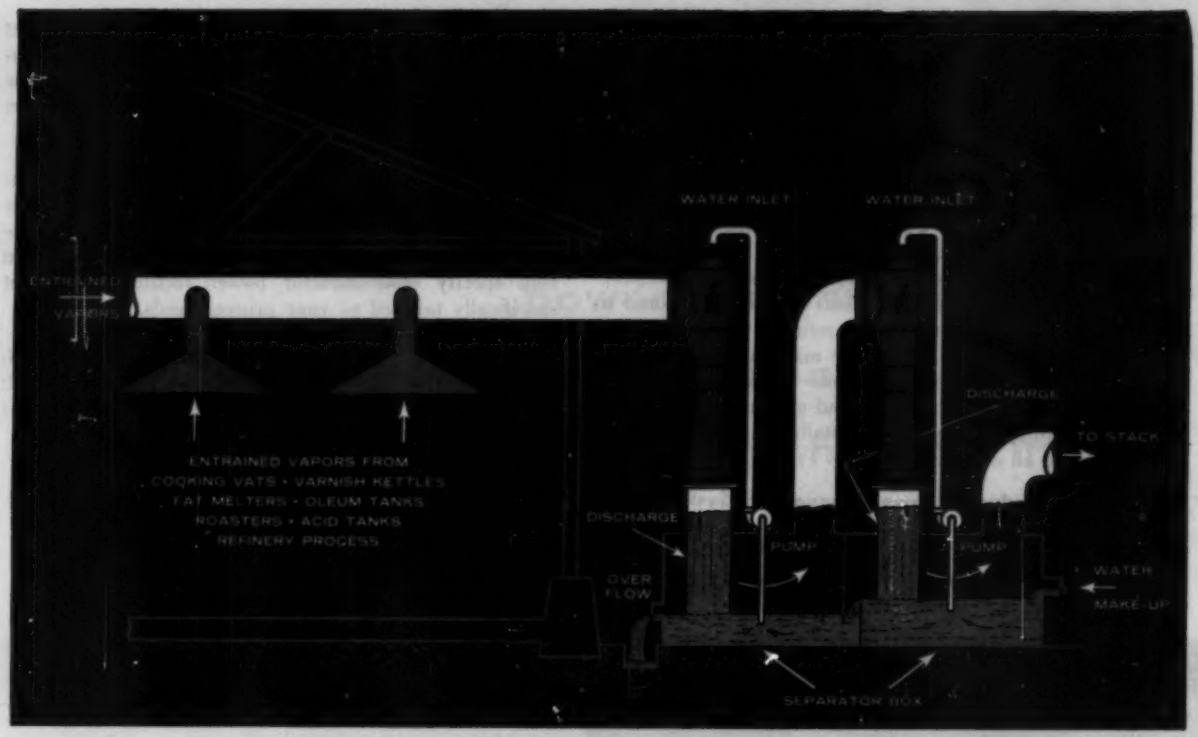


G-E AIR COOLED semiconductor power rectifiers are recommended for systems where d-c voltages exceed 400 volts. Trays contain several series rectifier cell assemblies, fuse, fuse monitor and indicating lights.



DIRECT WATER-COOLED G-E rectifier units are used in systems where d-c voltages do not exceed 400-v. Internally mounted air-cooled transformers (above) are sometimes used in smaller systems.

For more information, turn to Data Service card, circle No. 36



CONTROL OBJECTIONABLE FUMES, GASES, VAPORS

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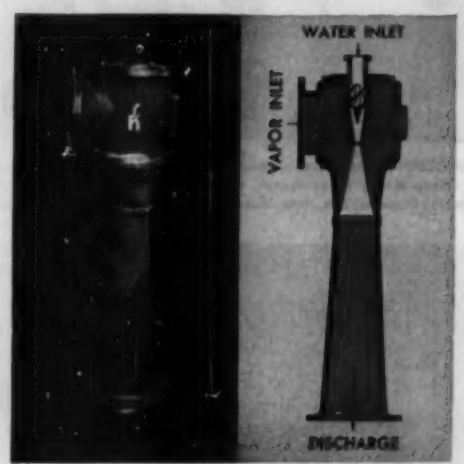
Photo and sectional drawing of an SK Fig. 4010 Fume Scrubber



A food plant in California uses an SK Fume Scrubber to condense steam and scrub oil vapors from cooking vats. A large chemical manufacturing plant on the eastern seaboard uses a battery of SK Fume Scrubbers to condense steam and purge entrained gas containing H_2SO_4, SO_3, H_2S, TiO_2, and ore dust. A mid-western manufacturer uses SK Fume Scrubbers to vent oleum tanks. A soap maker in Pennsylvania uses a scrubber to remove ammonia fumes from a plant building and cool the building at the same time.

From coast to coast, chemical and food processing plants, refineries, paint and varnish manufacturers, fertilizer, and other manufacturing plants are using SK Fume Scrubbers to control objectionable—sometimes dangerous—fumes, gases, vapors, and dusts.

These manufacturers have found that SK Fume Scrubbers are reasonably low in initial cost, require little maintenance, and are an effective means for conforming to local ordinances which prohibit the pollution of air.

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MARCH 1959

CEP.....trends

When the next round of plant-building?

For some time it has appeared that the next major round of new plant construction will take place as a result of pent-up technological advancement. This means that recovery from the present decline in new plant equipment expenditures should be predictable by watching announcements of new developments, and analyzing these in terms of their expected effect on other product lines in the chemical process industries complex. Although it is too early to assess their significance, some upturn in announcements of plans to go ahead with new construction has been noted, particularly as pertains to the Western U.S. Someone recently said that the 1957-58 recession started in the west, moved east; and that recovery is now doing the same.

It is always interesting to review the recovery time from previous recessions, wondering at the same time what the significance may be insofar as the present situation is concerned. From the February Business and Economic Review of The First National Bank of Chicago comes the following: "In the 1948-49 recession . . . plant and equipment expenditures continued to decline for nine months before turning up in the second quarter of 1950 . . . The bottom of the 1953-54 recession was in the second quarter of 1954, but it was not until a year later that businessmen increased their outlays for the expansion and improvement of manufacturing facilities . . ."

Whatever one's estimate of today's timing for such recovery, here is CEP's roundup of some of the technological developments capable of at least influencing a return to a state of expansion.

Synthetic fatty alcohols

From Continental Oil comes word that piloting is well on the way to completion, and a definitive commercial scale plant design may be announced shortly for the production of synthetic fatty alcohols under Ziegler license and additional Continental patent rights. Termed the ALFOL process, Continental's present schedule calls for a plant to be completed and ready for operation by 1961. Product alcohols will be aimed primarily at the detergent industry, opening up a new source of supply based on ethylene—which is of course a stable raw material. Continental believes that they can compete with natural products at the large volumes inherent in the detergent field.

Roundup from Chemical Economics Newsletter

The most recent (January) issue of the (bimonthly) Chemical Economics Newsletter, published by Stanford Research Institute, contains a number of indications of technological progress which may have lasting significance, as follows:

Carbon Black—Liquid hydrocarbons now make up more than half the total production of carbon blacks, with natural gas being displaced. The liquids are offering cost advantages, wider choice of plant location, and reportedly higher abrasion resistance —a quality desired for certain types of tires.

Our export of carbon black takes 25 percent of our total production. One of the reasons we have enjoyed such a market position is because of the large plants required. Now, with Sahara gas and oil, plus the European Common Market, France could enter into a scale of manufacture which might displace us.

On the plus side, a new polyethylene under development contains 50-60 percent carbon black, cross linked with the resin molecules. This could significantly add to the demand for black.

Dyes—paralleling the chronically depressed state of the textile industry, consumption of dyes has been considerably under the industry's manufacturing capacity.

Now a technological change in coloring methods associated with synthetic fibers offers hope of improving the market for pigments. With a technique known as spin-dyeing, pigments of fine particle size are added to synthetics in liquid form. Combined synthetics-pigments are then coagulated in a spinning bath, giving internal pigmentation said to be colorfast. Although used primarily in rayons, Dupont has already marketed some spun-dyed nylon.

Rubber processing chemicals—Synthetic rubber, which basically requires twice as much chemical additive per pound as natural rubber, is reported by CE Newsletter as under development in directions trending towards increased chemicals requirements.

Hydrofluoric Acid—Phosphate rock processors are expected to press for more economical methods for recovering by-product fluorides as a result of growing interest in air-pollution control. If competitive recovery processes are developed, plants are expected to be built that will result in levelling-off of other HF production.

Plastics—Look for a marketing drive to gain acceptance of polyethylene film bread wrapping—a step that could add a demand of 100 million lbs./yr. to polyethylene capacity.

Development of new consumer products made of resin-treated paper and cottons may be expected to further expand the market for plastics and resins.

Ethylene Oxide—Approximately 36 percent of all ethylene goes into the production of oxide, with 89 percent of this consumed in making ethylene glycol. Continuing efforts to increase the consumption of glycol antifreeze appear likely to succeed, particularly if the motoring public can be convinced as to the desirability of yearly changes of "permanent" antifreeze.

Styrene—With about 80 percent of all styrene consumed by synthetic rubber, and with the latter trending towards displacement of styrene with oil-extenders, look to continued development of new uses of styrene plastics as the basis for any further growth in styrene demand.

Hercules' "Maggie" now on stream...

Badger-Built plant

produces **99+% HNO_3**

without using sulfuric

At its new plant in Parlin, N. J., Hercules Powder Company is now producing better nitric acid concentrate for about 60% of the cost of conventional methods. Secret of Hercules' success: Application of the new company-developed "Maggie" process (that uses magnesium nitrate as a desiccant instead of sulfuric acid); selection of Badger to engineer and construct the first 50 ton/day plant.

Working closely with the Hercules staff, Badger came up with a number of engineering and construction innovations. To cite one example, the main tower was designed to use fractionating trays rather than conventional packing. This recommendation allowed a substantial reduction in the size of the column, savings of 20-30% in its cost.

Several months of operation have proved the soundness of the plant concept. Plant operation surpasses expectations; product is 99+% HNO_3; capital investment is cut 30 to 40%; operating expense has been halved; corrosion is greatly reduced.

Process licenses now available

The "Maggie" process is available for licensing from Hercules for both the United States and abroad. Badger can furnish the following: Complete information on licensing; preliminary cost and utility estimates for your own evaluation; design, engineering, procurement and construction services for your plant.

Write for brochure . . . includes flow diagram, technical and operating details. Badger Manufacturing Company, 230 Bent Street, Cambridge, Massachusetts.

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opinion and comment

Training for technologists in management

American business is sending its executives, and executives-to-be, to management training schools at the current rate of about 800,000 per year, according to the American Management Association. Last year, because of the recession, this figure dropped off to about 300,000, but has now bounced back to the pre-recession level. Courses taken cover creative thinking, decision making, financial matters, concepts in the control of human behavior, and so on.

It is estimated that about 1,000 companies are engaged in such activity, spending more than $2 million/yr. on the university programs alone. These take care of about 30 percent of the total "students," whereas another 30 percent receive their training from their own in-plant courses, and the remaining 40 percent from other outside groups, including professional societies among which the AMA is foremost in this field..

Allison V. MacCullough, a consultant in the management field, has made a continuing survey which has not only kept track of what various schools and other organizations are doing, but also has obtained some data on effectiveness, and costs. The latter, incidentally, are reported as $8,000 for a ten-week session at MIT (including housing and meals). Harvard's charges are $2,400 for thirteen weeks, Columbia $1,875 for four weeks, and Stanford $1,600 for eight weeks.

With such a program for taking care of management matters, one can well ask is enough attention being paid to the giving of comparable training on advanced technological concepts to both non-technical and technical management executives, as well as technologists who are to remain in straight technology but presumably be much more effective through such training? This is a big question, one which is being posed with the presumption that practices have not yet caught up with need. Much of the present management training activity arose from war-time practice, of which there was no technological counterpart. It seems obvious, however, that such technological training will be a great need, perhaps commensurate in scope with the present level of management activity.

Lunching with the "experts"

Recently, at the Cincinnati Annual Meeting, a "unit operations luncheon" was held. Well attended, and buzzing with conversation during the hour-and-a-half or so, the luncheon gave the impression of being quite successful as a means for participants to sit down with each other according to discussion subject and talk matters over with an "expert" assigned to the table. Plans now call for another such luncheon to be held at the forthcoming Kansas City meeting in May. For the information and guidance of all concerned, CEP has surveyed those who "ran" the tables at Cincinnati to get their views as to how matters went. The results (from 35 leaders reporting) are in summary:

...89 percent reported discussions were primarily about the practical, with 11 percent giving heaviest credit to the theoretical.

...60 percent felt that counsel regarding the solution of practical problems was an important result of their presence.

...56 percent reported theoretical explanations of practical phenomena as being a significant general topic of discussion.

From this it can be seen that most participants came with practical matters on their mind; few tables dwelt at any great length on fundamental theory.

Questions were asked regarding the length of the discussion sessions, and 59 percent thought the noon period was "just right." Some 18 percent would have liked to have had another hour (although several wrote-in comments to the effect that eating is unnecessarily distracting, particularly since it caused too much time to be spent on personal amenities). On the other hand, 23 percent indicated that such discussions could well go on for most of the afternoon, provided that a certain amount of mobility, or "table-hopping," would be possible.

In general, the "experts" who conducted the tables feel that a certain amount of advance preparation on the part of both leaders and participants would help matters a good deal. To this end, leaders should plan to cover certain topics, and with a certain amount of strategy as regards covering desired areas. Participants, knowing in advance of their first and second choices of subjects (it isn't always possible to sit at a table of first-choice subject), would do well to have at least one question thought out in advance to facilitate the discussion, and the eliciting of desired information.

Many leaders seemed to feel that their role was primarily that of conducting the discussions, keeping the talk moving over interesting areas. In other words, even those with the most profound reputations found that many participants got a great deal out of just exchanging views and experiences with each other. Of course, the experts had plenty to say, too, in the true role of "experts."

As is to be expected, a number of suggestions were made along the lines that a more effective end result might be had if a "smoker" or "bull session" format were to be employed, rather than the luncheon. Those of us who have for so long heard the appeals for "something more to do at at least one luncheon rather than listen to a speaker" believe that a similar survey of participants might very well turn up a preference for the luncheon format.

All evidence points to the "unit operations luncheons" being another successful kind of person-to-person contact medium available through attending Institute national meetings.

J.B.M.

◀ For more information, circle No. 5

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For more information, turn to Data Service card, circle No. 68

IN-PLANT POLLUTION CONTROL

Big $$$ outlay, plus the chemical engineers' processing approach, add up to big time expansion

THE PROBLEM of industrial wastes has many aspects, and must be attacked simultaneously from all sides by many professions—sanitary engineers, chemists, aquatic biologists, microbiologists, toxicologists, etc. But a leading part in any pollution abatement program must be taken by the chemical engineer.

Most chemical engineers are primarily concerned with the processes of manufacturing, especially in the "process industries." But they are also interested in the processing of wastes, and have already made major contributions to this field. However, because the chemical engineer does have his domain primarily in the plant, this is the logical place for him to work on pollution abatement.

The solution of any individual industrial waste problem has, in general, three principle phases. The *last* of these is treatment. If a waste must be treated we treat it—but first we do everything possible to avoid or minimize treatment. One means to this end is utilization of the receiving stream to absorb as much waste as it can without deterioration. This is a problem for the aquatic biologist and his associates. A second means is the prevention of waste in the manufacturing process. This is the job of the chemical engineer.

The chemical engineer has available several principles or measures to control pollution within the plant prior to waste treatment or discharge. Some of these are: changes in the manufacturing process, material salvage including water reuse and by-product recovery, good plant housekeeping, and the collection, segregation, and equalization of wastes.

Each industry has its own particular problems, various industrial case histories will be studied in up-coming issues of CEP, but the most important aspect of pollution control for the chemical engineer in all industries is in-plant control.

C. FRED GURNHAM, *vice chairman A.I.Ch.E. Pollution Control Engineering Committee. Adapted from Gurnham's introductory remarks as chairman of the "Pollution Abatement by In-Plant Measures" symposium at the A.I.Ch.E. Annual Meeting in Cincinnati.*

POLLUTION CONTROL FEATURES

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2. National Conference on Air Pollution —A Report 43
3. Environmental Changes and Water Pollution ..44
4. In-Plant Pollution Control in the Petroleum Industry 45

Typical of in-plant pollution control, these cyclone collectors at an Electromet plant are used with fog towers and bag collectors to give 99 percent efficiency in preventing coke dust reaching the air.

SURVEY REPORT

Air POLLUTION Abatement

..... *survey of current practices and costs*

W. L. FAITH,
Air Pollution Foundation, San Marino, California

This report* began as a survey of the chemical process industries to determine current practices in air pollution abatement, and the nature and cost of installations made since January 1, 1956. Answers were received from 95 of the 160 companies queried. The following summary of current air pollution abatement practices deals chiefly with the control of emissions from processing. Problems of smoke, fly ash, and sulfur dioxide from power plants have been omitted, even though in some cases control of these emissions is a major capital and operating expense item.

Much of the information was submitted on a confidential basis, so company names are mentioned only where the information has been published previously.

Chemical manufacture

The chief problems in the chemical industry, judging from the number of times they were mentioned, are dilute vent gases, acid mists, waste sulfides, oxides of nitrogen, combustible wastes, and dusts from a variety of milling, drying, and handling operations.

Organic Vent Gases. Catalytic combustion methods appear to be gaining acceptance in the abatement of vent gases containing organic gases and vapors. Three companies mentioned new installations for burning

the off-gases from phthalic anhydride plants. Others use catalytic incineration on varnish and resin kettle effluents and on enameling ovens. Two large companies still use water or caustic scrubbers, citing the fire hazard as their reason for avoiding catalytic units.

Where the gases are highly acidic, caustic scrubbers seem to be preferred; where the concentration is high, smokeless flares or activated carbon absorbers are used, depending on the value of the stream.

Acid Mists. No standardized procedure has been adopted for abating acid mist emissions. One company reported the following five different methods for sulfuric acid mist control at five locations: (1) mist filters and heated air for dilution; (2) tall stacks and heated air for dilution; (3) electrostatic precipitator; (4) electrostatic precipitator and mist filter; and (5) electrostatic precipitation, tall stack, and mist filter. Another company listed 99% efficiency for an electrostatic precipitator alone. One company scrubs an SO_3-SO_2 vent gas with sodium sulfite solution. Another mounted a cage-like framework above vents used to trap acid and alkali mists. The walls of the cage are of Fiberglas and of sufficient area to reduce the effluent velocity to between 100 and 200 feet per minute. These units have been particularly effective in reducing damage from

* *Biennial report on air pollution abatement advances in the C.P.I. by the Pollution Control Engineering Committee of A.I.Ch.E.*

the spotting of paint finishes.

Abatement of phosphoric acid mist with Venturi-type scrubbers and cyclones was described in a recent article *(3)*.

Waste Sulfides. The waste sulfide problem has many facets, including problems from H_2S and mercaptans as well as inorganic sulfides. Several installations have been made to recover sulfur from H_2S gases. Where recovery is not economic, caustic scrubbers are preferred for both H_2S and mercaptans. In one installation batch scrubbing is used. At the end of the run, the sulfur-laden caustic solution is chlorinated until no odor results from acidification. In another case, mercaptans are steam-stripped from a gas stream and the remaining noncondensables are flared.

Air pollution problems were also reported from the disposal of sulfide carrying liquid wastes. When these wastes come in contact with acids, H_2S is liberated. Suitable processing is oxidation to the thiosulfate and treatment with sulfuric acid. A similar problem was reported with disposal of a sodium sulfite solution. Acids in the sewers liberated SO_2, which then came up through the manholes. The same type of processing used for sulfides solved the problem.

Oxides of Nitrogen. Numerous installations were reported for removing the brown plume of tail gases from nitric acid plants and one from a niacin plant *(1, 4)*. Catalytic reduction of NO to nitrogen using a platinum alloy or other catalyst appears to be favored. Oxygen in the tail gases is first burned out by addition of propane or natural gas, and the oxygen-free gases are then passed over the catalyst where nitrogen oxides are reduced by reaction with excess hydrocarbon, carbon monoxide, or hydrogen.

A few new installations removed NO_2 from tail gases by scrubbing with soda ash solution.

Combustible Plant Waste. The disposal of combustible wastes is a problem of considerable magnitude in many plants. Several plants reported 12-20 tons per day of trash and rubbish. Open-pit burning has been largely abandoned in favor of well-designed incinerators. Many of these still require scrubbers or fly-ash collectors to produce a satisfactory emission. One company uses cut-and-fill disposal instead of incineration.

Dust. The dust problem continues to be common wherever dry solids are crushed, ground, milled, calcined, pelletized, dried, handled, or packaged. A noticeable trend is toward the pyramiding of various units to obtain maximum collection efficiency. Thus, dust traps are installed ahead of cyclone separators, with bag filters or scrubbers following. Over-all efficiencies of 97 to 99% are common. High-efficiency Venturi-type scrubbers are increasing in popularity despite high power requirements. Extremely dusty raw materials are being well wetted prior to handling. Collection of resin dust is still a problem because the dust absorbs moisture and coats the interior of collecting equipment.

Reduction of dust emissions from lime kilns does not appear to be standardized. Among methods recently installed are:

1. Replacement of rotary kilns with vertical kilns.
2. Use of cyclone scrubbers with 97-98% efficiency.
3. Centrifugal dust collectors.
4. Reverse-jet bag collectors.

One operator originally used cyclone collectors, replaced these with a spray tower, and now uses a wet scrubber. The lime slurry is sent to thickeners for recovery.

Plant Design, Location, and Operation. The trend to consider air pollution abatement when designing new plants and operating procedures is gaining widespread acceptance in the chemical industry. Two large manufacturers keep air pollution control in mind in locating new plants. One purchases considerable excess acreage for new plants to reduce the likelihood of creating real or fancied nuisances. Another makes wind-tunnel studies before erecting new structures in existing plants. **There is a definite trend toward taller stacks. More roadways are paved to avoid dust problems and for better housekeeping. Pressurized tank storage is included in original design considerations. One new petrochemical plant, which cost 35 million dollars, and not usually considered to have an air pollution problem, had 2 million dollars of air pollution abatement equipment built into the basic process design.**

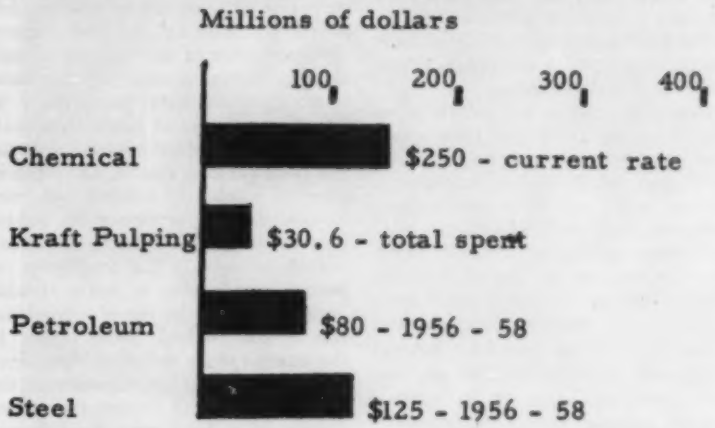
Another commonly mentioned means for abating air pollution was process change, such as substitution of low-volatility solvents for those of high volatility, lowering of process and vent temperatures, better process control, modification of operating practices, collection and absorption of vapors from storage tanks and loading operations. **Many multiplant companies have central air pollution abatement committees that meet regularly to consider air pollution problems.**

Cost of Abatement. We had hoped to be able to estimate the total annual cost of air pollution abatement to the chemical industry, but the hope was not fulfilled. Too many intangible factors are involved. As one correspondent said, "The costs of our various pollution-control programs are inseparable from other costs; many equipment installations have a dual purpose: pollution control and operating efficiency."

Nevertheless, two medium-sized companies with capital expenditures for air pollution abatement equipment amounting to $1,500,000 each for the three-year period stated that these expenditures were between 2.5 and

continued

THE COST OF AIR POLLUTION ABATEMENT
Industry estimates of expenditures



Significant in the above chart are the large expenditures of the chemical industry for air pollution abatement.

Air pollution control

continued

5% of total capital expenditure. This figure corresponds with the Manufacturing Chemists Association's estimate several years ago that the chemical industry was spending $40,000,000 annually on air pollution abatement. Recently, General Hull *(6)* of MCA, speaking before the Surgeon General's National Conference on Air Pollution, said that ". . . we can conservatively estimate the chemical industry expenditures for air pollution control or avoidance at from 200 to 250 million dollars a year."

Three smaller companies estimated their annual operating costs for abatement equipment at 15-20% of equipment cost, neglecting depreciation.

Pulp and paper industry

The chief air pollution problems in the pulp and paper industry center around Kraft mills. Major problems are fly ash (Na_2CO_3 and Na_2SO_4 "snow") from the burning of black liquor; dust from lime kilns; and mercaptan odors from digesters and evaporators.

Black Liquor Recovery. Electrostatic precipitators are normally used to control stack effluents from black liquor recovery furnaces; however, efficiencies are only about 90%, which is deemed inadequate. Considerable experimentation is going on in which wet scrubbers of various types are used to clean up the precipitator exhaust. One company claims a 99% cleanup from the use of a three-pass electrostatic precipitator.

Lime Kiln Dust. There is the same lack of standardization for lime kiln dust control as in the chemical industry (q. v.) Recent installations include dust scrubbers alone; dust scrubbers followed by cyclone collectors; chains in the feed end of the kiln; and various combinations of scrubbers, filters, and centrifugal collectors.

Odors. Mercaptan and sulfide odors arise from the relief and blow gases from pulp cookers, turpentine recovery units, and black liquor evaporators. Various types of water and caustic scrubbers and spray towers are used to reduce mercaptan effluents. One company collects the noncondensable methyl sulfides and mercaptans from a turpentine recovery system and burns them in the lime kiln. Several companies spend $100-$150 per day for odor counteractants in various effluent streams.

Cost of Air Pollution Control. The National Council for Stream Improvement estimates that the Kraft pulping industry in the United States has spent the following amounts on air pollution abatement equipment:

1. Electrostatic precipitators and Venturi scrubbers for recovery furnace stack gases	$24,142,000
2. Lime kiln exhaust equipment	2,661,000
3. Black liquor oxidation towers, chlorination towers, and other control methods for sulfur compounds	1,885,000
4. Stack gas cleaning equipment on fuel and bark boilers	1,973,000
Total	$30,661,000

Petroleum refining

The major air pollution problems of the petroleum refining industry are emissions of sulfur compounds, smoke and dust, and hydrocarbon evaporation. In those cases where petrochemical facilities are installed, many of the problems inherent in chemical manufacture also appear.

Sulfur Compounds. One of the gravest public relations problems of petroleum refiners is caused by malodorous organic sulfur compounds and hydrogen sulfide. Of secondary importance is damage to vegetation by sulfur dioxide.

Many refiners have gone to extreme measures to eliminate this cause of public complaint. Hydrogen sulfide is commonly recovered from waste gases by absorption in ethanolamines and subsequent recovery as elemental sulfur. In many cases mercaptans are also converted to hydrogen sulfide for similar recovery.

Other means reported for reducing sulfur-containing emissions are steam-stripping of sour waste waters, followed by burning stripped vapors; discontinuance of the burning of acid sludge; discontinuance of the acid treating of distillate (particularly in Los Angeles); use of mechanical seals on pumps to reduce odorous material loss from packing glands; and replacement of batch acid treaters with continuous treating processes (to reduce peak rates of sulfur dioxide emissions).

One refinery in the Southwest reported a reduction in sulfur dioxide emission of 98% by use of a combination of the methods listed above. In the interest of air pollution abatement, another company has discontinued the processing of acid sludge and manufacture of sulfuric acid. Acid is now purchased and acid sludge disposed of to another company.

In some refineries, hydrofining has eliminated sulfuric acid treatment of gasoline, heating oils, and lube distillates.

Stack Plumes. Unsightly smoke and dust plumes usually run a close second to odors in public complaints about refinery emissions. Most of the plume problems of refineries are similar to those in industry as a whole and therefore may be abated by cyclones, precipitators, good combustion, etc. Dust from fluid catalytic cracking units is a problem because the units are so large and the stacks so conspicuous. In most areas, these emissions have been greatly reduced by use of cyclones and electrostatic precipitators. It is interesting to note that in many plants the air entering the unit contains much more dust than is evolved in the effluent emissions.

Although steam plumes can hardly be classified as air-polluting effluents, the public often thinks they are. Accordingly, some refiners, particularly in the Los Angeles area, have started to eliminate these plumes. One unique installation is a delayed coker. Every seven hours, one of the six drums of the coker is filled with coke. When it is "blown down" (steam and water quench), steam is emitted for two hours at a peak rate of 100,000 pounds per hour. The steam passes to a knockout drum and then to a smokeless flare in which hydrogen and methane (about 3,000 lb per blowdown) are burned. Recovery of heavy hydrocarbons (20 lb per blowdown) is effected in the knockout drum. **The abatement installation, which completely eliminates a visible plume, cost $500,000.**

Another refiner bleeds hot air into a catalytic cracking regenerator stack to prevent aerosol formation in cold, humid weather.

Hydrocarbon Losses. Hydrocarbon vapors are both nonodorous and invisible, but ever since their involvement in Los Angeles' smog, losses by leakage and evaporation have been restricted. In Los Angeles, mandatory controls have resulted in the following abatement methods: floating roofs on gasoline storage tanks; covers on oil-water separators; common manifolding of vents and pop-off valves to a smokeless flare system; mechanical seals on pumps; vapor recovery at gasoline loading racks (both tank cars and trucks); and elimination of air-blowing of various distillates in favor of salt brightening (moisture removal by treatment with salt driers).

Some refiners have gone further with such practices as eliminating truck-flushing, chilling product lines

to storage tanks, etc.

Various hydrocarbon vapor control systems are being installed in refineries in other parts of the United States, even though there is considerable doubt as to the need for such measures except perhaps from an economic standpoint. One concern has been testing the French plastic blanket in a distillate run-down tank. Vapor loss has been cut by 94%. The method may be applicable to bulk station tanks.

Cost of Air Pollution Control. The cost of air pollution control to petroleum refineries in the United States can only be approximated. Since 1948 petroleum refiners in the Los Angeles area have spent $42,000,000, of which $2,600,000 was for air pollution research. A new refinery on the East Coast spent $7,500,000 on air pollution abatement facilities. An older refinery in the Middle West has spent more than $2,500,000 for air pollution abatement since January 1, 1956. Based on the information obtained in the current survey, it appears that air pollution expense for the petroleum industry in the United States during the past three years was 70 million to 80 million dollars.

The steel industry

The air pollution problems of the steel industry are largely caused by dust from various process operations, fluorides from open-hearth furnaces and sinter plants, and various noxious gases from coke ovens. A considerable amount of cooperative experimental work is going on within the industry, chiefly to find economic abatement methods that are effective on high-volume effluents.

Dust. Electrostatic precipitators and wet scrubbers have been used for a long time on *blast furnace* gases, not so much for air pollution abatement but because of the technical requirements for clean gas for use as fuel. One of the most annoying problems in the operation of a blast furnace is slips in the charge, with great losses of dust and gases to the atmosphere. One company is installing orifice-plate washers (to reduce dust to 0.02 gr./cu. ft.) and heavy-duty McKee tops on all blast furnaces as they are shut down for repairs.

Open-hearth furnaces present one of the biggest problems to the industry because of their tremendous size. Three plants have installed electrostatic precipitators to reduce outlet grain loadings to 0.02-0.05 gr./cu. ft. Since cost per furnace can well be more than $500,000, the search continues for less expensive equipment. One company is presently evaluating a Venturi-type scrubber for the treatment of open-hearth gases. The steel industry is also sponsoring research on the use of slag-wool mats for open-hearth fumes *(2)*.

The *fluoride* problem poses a somewhat different situation, since part of the fluorine emissions are gaseous. At Provo, Utah, United States Steel has reduced fluorine from its open hearths by adding ground limestone and hydrated lime to the sinter mix and again adding hydrated lime to the open-hearth waste gases. Gaseous fluorides are converted to calcium fluoride, which is removed in an electrostatic precipitator *(7)*.

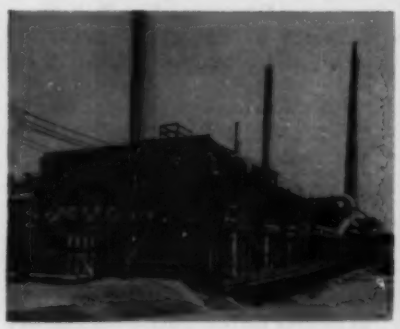
Effluents from electric furnaces are not as difficult to handle as those from the open-hearth. Nevertheless, seven sponsoring companies are carrying out cooperative tests in the Pittsburgh area to find the most suitable control method. In other areas, both electrostatic precipitators and baghouses have been installed. Precipitators are 97+% efficient and reduce outlet grain loadings to 0.02 gr./cu. ft. Baghouses with orlon bags are even more efficient, but the entering gas stream must be pre-cooled. One West Coast mill is currently installing Fiberglas bags.

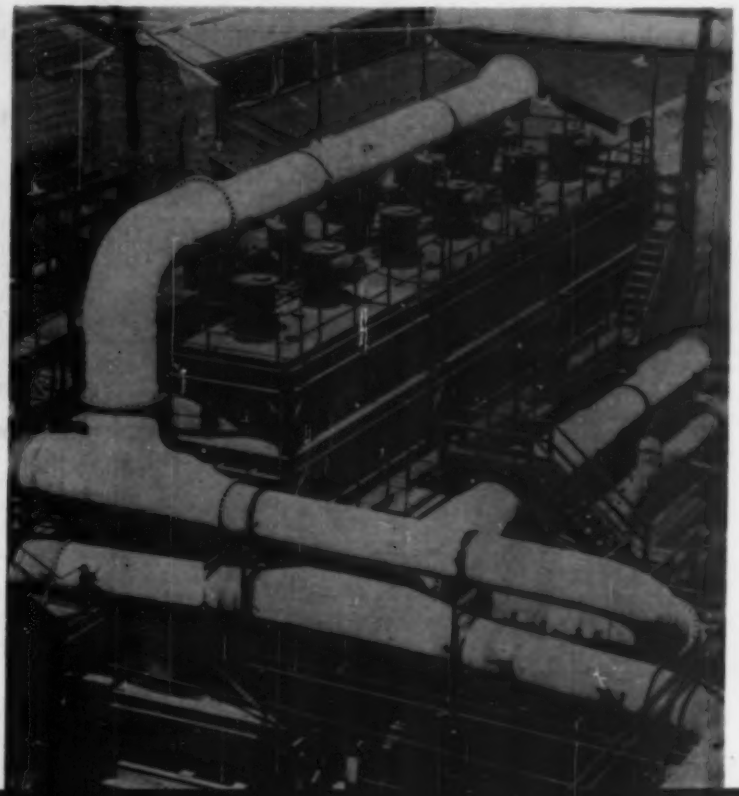
Dust from *sintering plants* has been controlled in a variety of ways. Centrifugal scrubbers, mechanical cleaners, cyclones, electrostatic precipitators, and various combinations of these have been installed in recent years. Purvance (loc. cit.) reported that at Provo the sintering plant previously released more fluoride compounds to the atmosphere than the open-hearth furnaces. The problem was alleviated by limestone and hydrated lime treatment, followed by the removal of solid particles in a battery of mechanical cyclones, followed by an electrostatic precipitator. Fluoride emissions were reduced by 96%.

Effluents from the new *basic oxygen processes* are being subjected to both

continued

New installation for pollution control





To remove acid mist from the main gas stream at this General Chemical (Allied) sulfuric plant (above), a double-deck row of coke boxes has been used. Now two batteries of Koppers' electrostatic acid mist precipitators (right) have been installed, will supplant second row of coke boxes.

Air pollution control

continued

wet scrubbing and electrostatic precipitation. Hot effluents from *scarfing beds* and *scarfing machines* are being treated similarly. Howell *(5)* estimates the cost of protecting one such machine at $100,000.

Coke Oven Effluents. A variety of methods are being used to control losses from coking operations. Dust from coke and coal handling and coal pulverizing and mixing is controlled by use of all types of common equipment. One plant uses double collecting mains on coke ovens ($350,000 per battery); another puts suction on ovens during charging. Howell (loc. cit.) reports that one company added self-sealing doors to 180 ovens, at a cost of $954,000. No suitable method is available for controlling emissions during coke pushing and quenching.

As in the chemical industry, *changes in operating practices* have also been adopted in the interests of air pollution abatement. One company has increased bed thickness and changed the type of grate in its sinter plant, changed blast-furnace operating practices to reduce slips, and built a contact sulfuric acid plant to reduce sulfur emissions by 15 tons per day. Another has shut down seven soaking pits, three iron cupolas, and one open-hearth, "all or part in the interests of smoke abatement." Many plants have replaced steam locomotives and cranes with diesel electrics.

Cost of Air Pollution Abatement. The size of the steel industry is such that most abatement methods are expensive. Figures reported by five companies on air pollution abatement expenditures since January 1956 were $1,000,000 (1 plant); $3,600,000 (1 plant); $20,000,000 (3 plants); $7,000,000 (several plants); and $10,500,000 (1 plant). Based on these figures, a conservative estimate for expenditures of the steel industry for air pollution abatement since January 1, 1956, would be $125,000,000.

Food industry

Only limited information was obtained from a few representative food processors. The portion of the industry handling dry solids (e.g., starch and flour) in various drying, milling, sizing, and packing operations have always minimized dust emissions for safety and economy. Thus, dust recovery can seldom be charged against air pollution abatement.

The food industry's biggest headache is probably odors, particularly from the decomposition of animal and vegetable proteins in liquid wastes. There appears to be a trend toward disposal by spray irrigation rather than by lagooning. One company treats these wastes with sodium nitrate and an odor-masking agent prior to spraying. Coffee roasters, candy factories, bakeries, spice mills, flavoring manufacturers, and many other segments of the industry emit various odors, which can be local nuisances. Complete control would involve passing all plant air through activated carbon adsorbers. Since this approach would often be economically prohibitive, odor-masking agents or odor neutralizers are often used.

Only two references were made to electrostatic precipitators. In one case, small units were used to abate oil mist from spraying machines in a bakery; in another, they were used to control smoke from a meat packer's smokehouse.

Few abatement costs were mentioned, except to state that they were small. One processor of dry foods had spent $200,000 on air pollution control equipment since January 1, 1956. Operating expense for this equipment was estimated at $29,000 annually (14.5% on investment).

Cement manufacture

The big problem faced by cement manufacturers is control of dusty plumes from kiln stacks. Many plants have installed electrostatic precipitators, but even at 98% efficiency, the plume is often still visible. A new type of barbed electrode called "Koronomax," incorporated in one plant's electrostatic precipitator, is said to have increased efficiency from 76% to 98%. Several methods have been used to control the residual plume from electrostatic precipitators. One involves the use of a glass-fabric filter bag in which the fabric is treated with a silicone compound to lubricate the glass fibers and thus overcome cracking (breakage) of the fabric. Another manufacturer uses a scrubber to eliminate steam from the residual plume. Still another adds a deodorant to suppress sulfurous odors. Many installations have cyclone collectors ahead of the precipitator.

Whether the recovered solids are useful or not appears to be a matter of opinion. One manufacturer points out that recovered solids should be returned to the system and that recovery is a long-term economy measure. One says the alkali fume recovered by the precipitator is not useful and presents a disposal problem.

Cost data received from the cement industry was fragmentary, so no overall estimate can be made.

Miscellaneous process industries

Tire manufacturers and rubber reclaiming plants apparently have no unusual problems. Bag filters are used to recover carbon black from Banbury mixers and dust from tire buffing, etc. Scrubbers are used to control odors from various operations, such as gum dip driers. The major tire manufacturers have each been spending about $100,000 annually on air pollution control.

Drug industry problems are usually concerned with odor control from

. . . . . in a new $35 million petrochemical plant

$2 million for air pollution abatement equipment

fermenter exhausts, animal rooms, noxious gases, and malodorous sludges. Scrubbers and odor-masking agents are normally used. Expenditures for air pollution control are thus relatively minor.

Few data are available from the **fertilizer industry** at this time because of extensive litigation under way in several parts of the country concerning alleged fluoride emissions from superphosphate plants. Normal dust problems are handled with conventional cyclones and wet scrubbers. Odors of ammonia and the ammonium chloride cloud from granulating process plants are difficult, and as yet unanswered, problems.

No unusual problems were reported by the **ceramic industry**. One manufacturer reported a capital expenditure of $500,000 for air pollution control equipment, with annual fixed charges and operating costs of $90,000 (i.e., 18%).

Sizable expenditures were reported by several *metallurgical* concerns. For various types of plants costing between 100 million and 300 million dollars, the capital cost of air pollution abatement equipment was estimated at 1-1.5% of total capital cost. Since many of these plants are built in isolated areas with favorable wind patterns and no agriculture nearby, costs for air pollution abatement are much less than they would be in settled communities.

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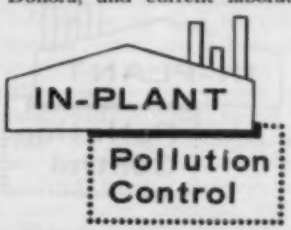
The Pollution Engineering Committee of A.I.Ch.E. is made up of 15 members from industry, five from educational institutions, and 3 from government. For 1959 it is headed by W. L. Faith, the author of this article, and the vice-chairman is C. F. Gurnham.

1958 National Air Pollution Conference—*a report*

An audience of more than 900 persons converged on Washington recently to attend a National Conference on Air Pollution called by Surgeon General Leroy E. Burney. Air pollution control and health officials, representatives of all major industries, research scientists, physicians, engineers, politicians, lawyers, farmers, homemakers, and just plain citizens—all came to listen, to put in a word, to grind axes.

Health aspects

Burney, opening the Conference, called attention to U.S. Public Health Service studies showing that incidence of cancer of the lung, stomach, and esophagus, and of arteriosclerosis and other heart diseases among city dwellers is greater than among rural people. Inasmuch as general air pollution shows a similar variation, it is a logical suspect as a contributing factor. These generalizations, together with analyses of specific air pollution incidents, such as Donora, and current laboratory



research programs, were hashed over in a full day's session of a panel on *Health Aspects of Air Pollution*. At the end of the session, the panel recommended that health research be accelerated by the U.S. Public Health Service—but not to the extent of a "crash program."

Industrial accomplishments

Four major industries (steel, automobile, chemical, and petroleum) reported on their accomplishments during the first day's plenary session. Panels on *Sources of Air Pollution* and on *Control Methods and Procedures* went into more detail in these areas. Both groups, in their summaries, called for more quantitative information on industrial emissions, establishment of tolerance thresholds, and determination of the relation of emissions to effects. The panel on *Control Methods* suggested that more effective utilization could be made of present knowledge, and called for codification of control equipment.

As might have been expected, there was some criticism of industry on general grounds for being responsible for air pollution and not doing enough about it. The big political guns, however, were leveled at the automobile industry. In the sessions on *Economic and Social Effects of Air Pollution*, several speakers questioned the adequacy of the $1 million-a-year research program of the auto companies. No constructive recommendations were made, however, except for a "healthier" car.

Responsibilities of the federal government

Each panel in its summary recommended extension, and some, expansion, of Public Law 159, under which the Public Health Service carries out its air pollution studies. The act authorizes an annual appropriation not to exceed $5 million, but, to date, Congress has never appropriated the full amount.

Several panels called specifically for more research in development of inexpensive instruments and better analytical techniques; aid to local agencies; more training programs for air pollution personnel; and systematic collection and better dissemination of information. The panel on *Extent of Air Pollution* recommended more air monitoring on a national basis—not only a larger network for collection of particulate matter, but expansion into the field of measuring various gases such as sulfur dioxide, nitrogen dioxide, and carbon monoxide.

A special report for CEP by W. L. Faith, managing director of the Air Pollution Foundation.

Environmental changes and water pollution

Mark D. Hollis
U.S. Public Health Service, Washington, D.C.

Time moves on—and with it come great changes that are moving at an accelerating pace. Early in the century conditions were simpler—the nation's population was small and dispersed (two-thirds rural); industry was just beginning to realize its potential; time was an ally; life moved at a relatively leisurely pace.

Today the situation is vastly different; we have undergone transition from a rural to an industrial economy; the population has more than doubled and is concentrated (two-thirds urbanized); and we are in the midst of an unprecedented area of industrial and metropolitan development. We deal now with the full implications of a tense, highly-productive, competitive, socially unstable, and technologically superb economy. Time is no longer an ally—we move at a hectic pace.

The resultant effects of these changes will tax our natural resources, especially air and water . . . at the same time the sheer weight of human congestion in a technological setting will contribute contamination of ever greater volumes and complexities.

As one views the logistics of the future water supply problem—with due allowance for redistribution between watersheds and predictable augmentation—the concept of maximum reuse comes sharply into focus. And on this, water quality is the key.

In our more congested basins, surface waters are already being reused many times as the streams flow from outfalls to intakes. This means that the growing and changing problem of water pollution becomes one not only of economics, but one very definitely of public health. Already more than 100 million people depend on surface streams for drinking water. By 1980, this figure will likely approach 150 million.

Concentrations of people and machines in a technological setting create huge volumes of wastes. To the extent that these overtax and deteriorate essential water resources, we are in trouble; and effective remedial actions are, at best, difficult to work out, and even more difficult to reconcile with the various interests involved.

In water resources, we must also remind ourselves that in the past we have dealt for the most part with bacterial pollution and its pathogenic potential; with natural organics, the behavior of which we so well understand; and with limited amounts of chemical contaminants of fairly well established toxicity and behavior. The problem now broadens to include an array of new types of pollutants—petrochemicals and other synthetic organics (chemical conglomerates of all types), and radioactive wastes. The behavior of much of this we do not adequately understand, and even less do we understand all the health effects. The future must be viewed in terms of the composite effect of such wastes, and we must expect an ever-increasing number of additional contaminants—adding new dimensions, new magnitudes—new headaches.

As far as bacterial contamination is concerned, our sanitary barriers and practices are, I think, up to present and anticipated need. On water supplies, we are developing a better understanding of the virus potential. However, in all candor, we are not nearly so confident about the probable build-up of the non-infectious contaminants in streams.

The engineer has worked with chemical wastes largely from the standpoint of economics—of moderating their composite effect on water uses—on aquatic life, on taste and odor problems, on interference with normal operation of treatment processes.

In a look ahead, it seems clear that more trained personnel will have to work in these areas. Certainly, more sanitary engineers are required in industry, in private practice, and in public agencies. These men will need even broader training in chemistry, physics, and biology. This introduces a real problem. The forward surge of technological progress places great demand for engineering research on our schools of technology and related centers.

This need, and it continues to increase, has influenced not only the type of research resources at our engineering institution but, to a large extent, the type of graduate study pursued by engineers.

The resultant effect is continually to decrease the research potential and the graduate level manpower in the field of sanitary engineering. This further supports the contention that man is not committing enough of his technological capacity to the task of moderating the adverse influences of his great progress.

Condensed from a talk by Mark D. Hollis, Assistant Surgeon General and Chief Engineer, U.S. Public Health Service, delivered before the Annual Meeting of A.I.Ch.E. in Cincinnati, December, 1958.

In-plant pollution control in practice

1. Petroleum industry

Sidney O. Brady
Humble Oil & Refining Co.
Baytown, Texas

Waste control must be considered not only during the development, selection, and design stages of any new plant or unit, but also in the case of any major modification of existing facilities. Here are the practical considerations.

EXPERIENCE has proven that waste control by in-plant measures in refineries is entirely practical. In many cases a satisfactory effluent can be produced by extensive use of in-plant methods. In other cases a combination of in-plant control and total effluent treatment is required to produce a satisfactory effluent. In these cases the in-plant measures reduce the quantity and strength of the waste waters to the point that appreciable savings are realized in investment and operating costs for the facilities provided for treating the total effluent.

There are many uses of water in refinery operations, which can be reduced to four basic uses:

1. Heat transfer agent.
2. Prime mover for steam power.
3. Solvent for chemical reactions.
4. Process agent for vaporization and system vapor-pressures.

In these uses, water becomes contaminated with a wide variety of materials: the sulfur, nitrogen, and oxygen derivatives of petroleum hydrocarbons; treating agents such as lime, caustic, acid, ammonia, various clays, phenols; and an assortment of catalysts from various treating processes.

There are two approaches to the solution of the waste disposal problems in a refinery. The first is to install facilities to treat the total effluent, rendering it innocuous to the marine life in the receiving body of water, such as: chemical treating, biological stabilization, air flotation, aeration, or any combination of these. The second approach is to use preventive measures to reduce the amount, or strength of polluting wastes, or to eliminate the production of certain wastes. This approach is termed *in-plant control*, as opposed to the *total treatment* approach. Although total treatment might still be necessary after all feasible in-plant measures are taken, the reduction in volume and strength of wastes achieved by the in-plant measures can reduce the investment for treating facilities, as well as the operating costs for those facilities.

The measures described in Volume III of the American Petroleum Institute Manual on Disposal of Refinery Wastes represent the thinking of a large number of experts in this country, on the subject of waste control by preventive or in-plant methods. These measures will be used as the bases for discussing the effectiveness of in-plant means for solving the waste disposal problems.

Engineering design considerations

Waste control must be considered during the development, selection and design stages of new refineries or units, or of any major modification of existing facilities. Although it might appear that this would apply mainly to new refineries and only in a limited way to refinery with *existing* processes and equipment, this is not strictly true. In the highly competitive petroleum refining business, process changes are continually being made to place the refiner in a better position with respect to product quality or costs. Therefore a well-planned, long-range waste disposal program, taking full consideration of the engineering design principles described below, will effect an improvement in effluent quality in a short time.

Separate drainage and sewer systems. Some new refineries have as many as six separate sewer systems,

continued

Petroleum industry

continued

which may include storm sewers, sanitary sewers, clean process water sewers, and one or more sewers for the collection and segregation of various "dirty" or contaminated streams.

Unfortunately, many older refineries were built with only one sewer system to handle *all* waste water streams. Sanitary sewage solids caused the formation of large amounts of emulsions and tended to fill separators. Storm water run-off flooded the sewer-separator system, flushing it out to the receiving stream. In many cases the contaminated process water was mixed with the relatively clean cooling water. In a refinery using recirculated cooling water cooled by cooling towers, the clean water will constitute from 85 to 90% of the total effluent stream. The mixing of contaminated and clean waters in one sewer requires gravity-separation equipment of a size to handle the combined stream. Any further required treatment would have to treat the total volume of water. It is now general practice to install separate drainage and sewer systems.

In general, it is desirable to:

1. Collect and drain cooling water and unpolluted storm water. Such waters usually require a minimum of treatment. A high-velocity oil-water gravity differential separator is usually adequate to collect accidental oil spills.
2. Collect and drain polluted water.
3. Collect and treat sanitary sewage.

Although it is expensive to install additional sewer systems in an existing refinery, this is sometimes less expensive than to provide facilities for treating the total effluent stream, especially if the refinery has many buried oil lines, and if chemical treatment is required.

Segregation of Waste-Water Streams. It is often advantageous to segregate waste streams for separate handling, for example:

1. Collection of spent caustic solutions and spent acid solutions under controlled conditions to obtain a neutral solution.

It is not economically feasible to concentrate these solutions for further use in the refinery or for sale to other industries. Therefore, to avoid their adverse effect on the quality of the effluent, these waste chemical streams are segregated in a separate gathering system. Undesirable material is then removed by flocculation, clarification, and filtration of settled sludge, Figure 1. Sulfide-bearing waste streams cannot be treated in the flocculation section because of the possible release of H_2S on contact with acidic materials, thus creating a hazard. Sulfide waste chemicals are concentrated and sold.

The waste chemicals are collected and discharged into an earthern impounding basin (retention time of approximately one day) thus insuring a feed stock of relatively uniform quality to the flocculation system. Facilities are provided for the addition of acid to the influent stream in a mixer section ahead of the impounding basin to insure a low-enough pH to spring the organic acids. The impounding basin is equipped with skimming facilities for the removal of the acid oils released upon acidification of the combined waste waters. The acid oil is collected in a storage tank and is processed through a corrosion-resistant system in the filtration plant. Water from the impounding basin flows by gravity into a two-stage flocculation sump. In the first stage sufficient lime is added to cause flocculation. Selected spent caustics are added in the second stage to raise the pH to the desired flocculation range. The water is then pumped to a coagulator for clarification. The sludge settles to the bottom in six compartments and is removed by a pump to a storage tank equipped with a stirrer. The sludge is then filtered for dewatering in the filtration section of the plant.

2. Wastes of high-solid content are segregated, since high-solids wastes tend to form emulsions and thus increase the oil content of separator effluents. At the Baytown refinery these streams are pumped to a large settling pond where the solids separate out.

Water Conservation and Re-use of Water. In refineries located on large lakes or rivers the waste disposal problem is simplified by the dilution afforded by the large amount of once-through cooling water available. For many refineries, however, water supply is a serious problem*, and water conservation is emphasized.

The use of cooling towers and recirculated cooling water is one of the most commonly used water conservation measures. Proper operation of cooling towers, with chemical treatment of the water to control corrosion and cooling tower degradation, allows maximum recirculation of the water. Depending on the quality of the available make-up water, it may be possible to recirculate water 20 or more times. At Humble total incoming water amounts to approximately 35 million gal./day; if once-through cooling water were used, it would require over 600 million gal./day.

Another well proven water conservation measure that is growing rapidly in importance is the use of air-cooled exchangers. A typical installation is shown in Figure 2. These coolers are justified because of economic considerations rather than water conservation, but the end result is the same. Some of these coolers have been in service for over three years, during which time dependable performance and low maintenance costs have been established. The cost of cleaning the tube side of air-cooled exchangers is less than the cost of cleaning comparable water-cooled heat exchangers.

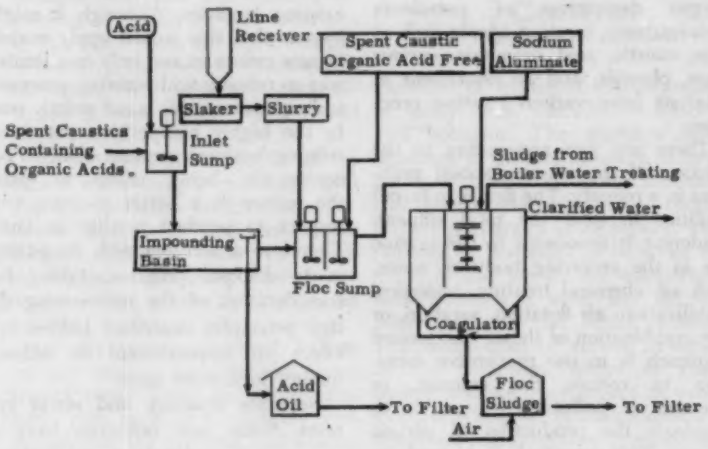


Figure 1. Treatment of segregated wastes.

* *At least two refineries in this country depend on treated sanitary sewage from neighboring cities for a portion of their water supply.*

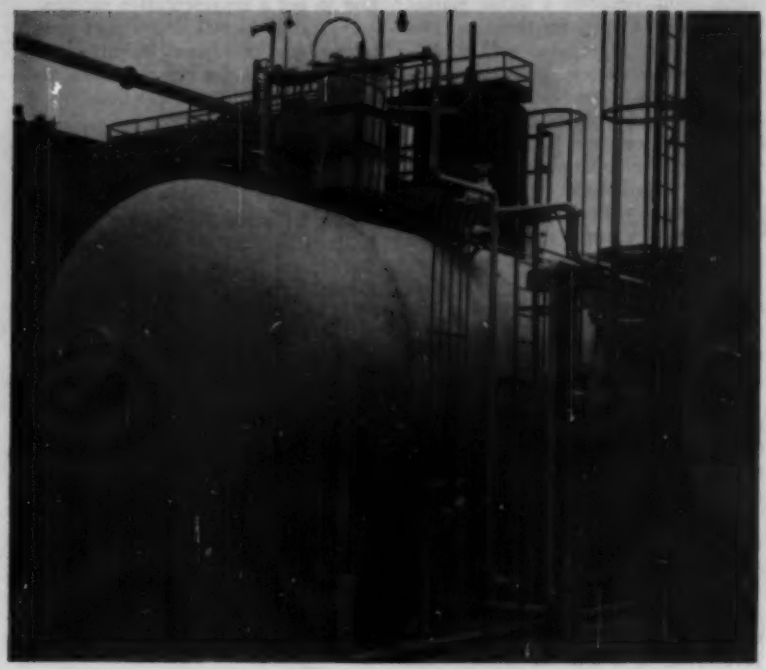


Figure 2. (Left) Typical air-cooled exchanger installation.
Figure 3. (Below) Typical electrical coalescer installation.

Maintenance and repairs peculiar to air-cooled exchangers such as fan maintenance and cleaning of fins is very nominal.

Education of plant personnel to turn off faucets can effect some reductions in water usage. The total water volume that can be saved this way is relatively small; however, the saving can be attained with little or no investment.

Other water conserving methods common in the industry are:

1. Substitution of mechanical seals for water-sealed pump glands.
2. Replacing barometric condensers with surface condensers.
3. Use of electrical coalescers to remove treating chemicals from chemically treated hydrocarbons. This can eliminate a water wash step; resulting not only in water saving but a saving in chemicals as well.

In most of the refining industry full advantage has not been taken of the possibilities of re-using water.

One common example of water reuse is that of condensate return to boiler feed, resulting in heat savings and boiler-water treating costs. This double saving accounts for the fact that this is a rather common practice.

Process design modifications that effect waste control

Process Selection. Waste control problems are often the deciding factors when considering alternate processes; thus, waste control should be considered early in the development of a process. It is becoming common practice to require that any new process solve its own waste problems. This means that waste disposal facilities must be included in the economics of the process.

Many difficult waste disposal problems may be eliminated by the adoption of new processes that either eliminate or reduce the production of contaminants. Examples are:

1. The elimination of acid treating of hydrocarbon streams by the adoption of Hydrofining. (Acid treating of hydrocarbons resulted in the production of acid sludges and acid wash waters. The caustic neutralization of the acid treated hydrocarbons resulted in the production of spent caustics containing organic acids or soaps, and wash water streams that contained some of the soaps. The acid sludges were commonly burned under boilers with the resultant SO_2 creating an air pollution problem. The spent caustics and alkaline wash waters were very difficult to dispose of, contributing a high oxygen demand to the effluent, and the soaps were bad emulsion formers. Not only can the production of these contaminants be eliminated by the Hydrofining process but in most cases a higher quality product is realized.)

2. Elimination of acid treating of aromatics by installation of clay treating facilities. (Aromatic hydrocarbons are quite commonly acid-treated to meet a quality specification. This operation produces an acid sludge whose caustic neutralization results in a spent caustic containing aromatic sulfonate soaps. These soaps are good organic wetting agents and even traces of these materials in the effluent can result in the formation of large amounts of emulsions. Substitution of high-temperature liquid-phase clay treating not only eliminates all of the above waste streams but produces a better quality product.)

3. Substitution of continuous processes for batch treating aids pollution control by eliminating peak discharges of wastes, and reduces the capacity needed for waste treatment.

4. Use of processes that include regeneration of the chemicals used for sweetening, hydrogen sulfide removal, and mercaptan extraction will avoid or reduce the problems associated with disposal of caustic wastes.

Product and Chemical Losses. Waste disposal problems may be reduced by controlling the losses of product and chemicals by various process devices. Some examples are:

1. Electrical Coalescers, which consist of a treating vessel containing electrodes that subject the treated hydrocarbons to a high-voltage direct-current field. Under the influence of this field, induced charges cause droplets to become attracted to one another, becoming coalesced into droplets of sufficiently large size to settle readily. The coalescers are used following acid treating, caustic treat-

continued

Petroleum industry

continued

ing, and water washing. By eliminating, or reducing, the chemical carryover from a treating process the final water-wash step is either eliminated, or the wash water is reduced in chemical content. The chemical recovered in the coalescer may be reused, reducing the chemical cost of the operation.

In one refinery an electrical coalescer was installed as a pollution control measure to reduce the amount of caustic needed to neutralize alkylate from a sulfuric acid alkylation process. Better than 95% reduction in acidity was effected, with a resultant reduction in the amount of caustic necessary to neutralize the stream. A typical electrical coalescer installation is shown in Figure 3.

2. Rock salt towers are sometimes used to remove traces of treating agent from hydrocarbon streams, thus eliminating the need for water washing.

3. Beds of steel or glass wool have been used to coalesce and remove traces of treating agent from light hydrocarbon streams.

Recovery and utilization

Procedures for waste recovery and use vary from the installation of complex processing plants to simple collection and sale of the chemicals. Some typical examples of recovery and use are:

Humble's methods for handling spent caustics. Between 50 and 60 tons/day of NaOH are used in the various refining processes at the Baytown Refinery. Disposition of the spent caustics is made in one of four ways depending upon the characteristics of the waste stream.

1. Sulfide-Spent Caustic — For several years Humble collected and concentrated the sulfide-spent caustics for sale to an outside consumer. Facilities for collecting these caustics have been improved and expanded from time to time. A Buffalo-Vac single-stage evaporator has been installed to concentrate the material collected. The gases and steam evolved from this unit are burned in a fume burner and discharged through a 150-foot stack to prevent air pollution.

2. Spent Caustics Containing Organic Acids — These tend to form emulsions in the sewer-separator system and contain oxygen-consuming materials. At the start of the effluent-improvement program these materials were discharged to the Effluent Flocculation Unit, for neutralization and clarification. Recently a stable market has been developed for these caustics and they are segregated and sold.

3. Spent Caustics Containing Mercaptides — It is possible to regenerate mercaptan-spent caustics by air-oxidizing the mercaptide to the disulfide, which can be separated. The caustic can then be re-used.

4. Weak Caustic Streams—A number of weak caustic streams are uneconomical to concentrate or re-use. These streams are treated in the Effluent Flocculation Unit previously described.

Recovery of sulfuric acid from acid sludges and waste acids.

1. Acid sludges may be hydrolyzed to produce dilute black acids of 30-60% H_2SO_4 content. In some cases these acids are concentrated by evaporation and fortified with SO_3.

2. Acid sludges and waste alkylation acids can be decomposed in a sludge conversion process and converted to fresh 98% acid.

3. Acid waste streams are often sold to manufacturers of fertilizer.

Hydrolysis of aluminum chloride and hydrocarbon complexes. These materials which are used as catalysts in various treating processes are being hydrolyzed in one refinery to form a solution of aluminum chloride and a hydrocarbon layer. The aluminum chloride is used as a coagulant for waste water and the hydrocarbon layer is returned to the refinery for reprocessing. One refinery has waste disposal facilities in the design stage which include the use of aluminum for a flocculating agent for treating waste water, and an acid treating step for the floc sludge to recover the aluminum for re-use.

Water-softening sludges to remove fluorides from wastes produced by HF alkylation. This type of sludge can also be used to neutralize acid waste waters, thus putting the sludge back into solution.

Recovery of Oil. Slop oil recovery is practiced by most refineries. While chemical treatment of slop oil emulsions can produce a satisfactory separation in many cases, the water layer is usually highly contaminated. To avoid this many refineries resolve slop oil emulsions by mechanical means; usually by pre-coat filters or centrifuges. There are several unique oil recovery methods practiced:

1. Oil recovery from sub-soil. Oil from leaks and spills may be trapped in the sub-soil formations and recovered by means of shallow wells.

2. Make sampling lines on large units into a recirculated system so the sampling connection is very short, making it unnecessary to drain a long line to get a representative sample.

3. Install special drains and sumps to collect oil from leaking pump glands. When the sump is filled it is pumped back to product lines.

Local pretreatment or disposal

Treatment of waste streams at the source is one of the fundamental precepts of in-plant treating. Typical are: Sour water strippers. A number of refineries have installed facilities to strip NH_3 and H_2S from condensate waste water. The H_2S evolved is commonly charged to a sulfur recovery unit. These strippers, of many types, use air, steam, or natural gas.

Where spent caustic streams cannot be sold they are sometimes disposed of by one or more of the following methods:

1. Neutralizing with flue gas.
2. Neutralizing with acid wastes.
3. One-step stripping and oxidation with air and steam.
4. Injection into deep wells.
5. Controlled discharge into waste stream.

Waste waters containing phenols are sometimes charged to desalters, and have been used to control after-burning in the catalyst regenerators of catalytic cracking units. Biological stabilization of these wastes is becoming a common practice. Trickling filters, activated sludge, and biological oxidation in cooling towers have all been used to remove phenols from waste waters.

Operation control

Changes in operating procedure may materially reduce waste disposal problems. To be effective these control practices must have the interest and support of management, process supervisors, and the operators. It is important that some specific group have control authority and responsibility for the quality of the waste water that leaves the plant. This group should, with the aid of the laboratory, originate and maintain a complete record of data concerning sources, characteristics, and quantities of all wastes and waste-water streams. These data should be reported periodically. Accurate, up-to-date maps and plans of all waste disposal facilities should be maintained. One of the most important functions of this group is to maintain a continuous educational and training program for the operators and management.

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High temperature chlorination in a fluidized bed

. . . . gets magnesium from olivine ore

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In the Cascade foothills about twenty miles northeast of Mount Vernon, Washington, there exists a large mass of rock which presents a challenge to chemical and metallurgical engineers. This mass of high-grade dunite, or olivine, about ten miles long and three miles wide, makes up the Sisters Mountains from their base at approximately 2500-ft. elevation above sea level to the summits at about 6500-ft. elevation. Chemical analyses of numerous samples from this dunite body have shown a large part of it to have the following average composition:

MgO	49.2%
FeO	7.25
Al_2O_3, MnO, CoO, NiO	2.0
CaO	0.01
SiO_2	41.8
Ignition	0.2

The size of this olivine deposit and its extremely high MgO content have been the incentive for many attempts to treat it chemically for the recovery of both magnesium compounds and magnesium metal. Bengtson *(1)* in 1955 reviewed the entire problem of magnesium extraction from olivine and concluded that chlorination at a temperature high enough to volatilize all magnesium chloride formed was the best approach to the problem from the standpoint of ultimate metal recovery. A thermodynamic study gave these energy relationships for possible chlorination reactions:

$$Mg_2SiO_{4[c]} + 2CO + 2Cl_2 \rightleftarrows 2MgCl_{2[g]} + SiO_{2[c]} + 2CO_2 \quad (1)$$

$\Delta H_{1000}^{\circ} = -49{,}800;$
$\Delta H_{298}^{\circ} = -157{,}000;$
$\Delta G_{1000}^{\circ} = -82{,}500$

$$SiO_{2[c]} + 2Cl_2 + 2CO \rightleftarrows SiCl_{4[g]} + 2CO_2 \quad (2)$$

$\Delta H_{1000}^{\circ} = -82{,}300;$
$\Delta G_{1000}^{\circ} = -16{,}300$

$$Mg_2SiO_{4[c]} + SiCl_{4[g]} \rightleftarrows 2MgCl_{2[g]} + 2SiO_{2[c]} \quad (3)$$

$\Delta H_{1000}^{\circ} = +28{,}270;$
$\Delta G_{1000}^{\circ} = -54{,}500$

Chlorination of olivine and silica was therefore found to be not only thermodynamically feasible, but virtually irreversible except in the case of silicon tetrachloride.* This substance, at equilibrium in the presence of magnesium silicate, would be almost quantitatively reconverted to silica according to reaction (3). The interesting consequence of this fact is the possibility of avoiding net formation of silicon tetrachloride in a chlorination apparatus, and providing efficient solid-gas contact in the presence of an excess of unreacted silicate.

Reactions (1) and (3) above were investigated experimentally using a small fixed bed with encouraging results *(1)*. Magnesium chloride was produced when a mixture of nitrogen and silicon tetrachloride was passed through a bed of olivine maintained at 1300°C. Subsequent examination of the particles disclosed the formation of a porous film of silica on the surface of the particles. Reaction (1) above was used to chlorinate, remove, and condense up to 90% of the MgO-FeO content of mineral as large as −48 + 65 Tyler mesh, while chlorinating only 10% of the silica content. Unchlorinated silica was observed to form a loosely adherent layer of fine christobalite crystals on the surface of the particles as chlorination proceeded. Silica was observed not to chlorinate until very late in a given run, when presumably fresh mineral was not readily available to the chlorinating gas. Some experimentally measured chlorination rates were as high as 110 lb. of metallic chlorides/hr./cu.ft. of bed volume through conversion of MgO-FeO as high as 65%.

It was also concluded *(1)* that the rate-controlling factor in the chlorination of magnesium silicate according to Reaction (1) appeared to be diffusion of gaseous reactants through the partially stagnant gas in the interstices of the silica residue. Either chlorine or carbon monoxide, depending upon particular concentrations and diffusivities, could be considered as the limiting reactant. All other gases present were considered to be inert insofar as diffusion of the limiting reactant was concerned. For this situation the moles of limiting reactant A transferred per unit time through the residue of film thickness z, according to the following equation

$$N_A = \frac{D_A \pi A (P_{A_1} - P_{A_2})}{RTzP_{BM}} \quad (4)$$

was considered to approximate the chlorination rate.

Objectives

The observed high chlorination rate and the calculated high heat genera-

continued

* *Units are g. cal. and g. moles; temperatures are °Kelvin. ΔH_{298}° is calculated for magnesium chloride in the crystalline rather than in the gaseous state.*

High-temp chlorination

continued

tion rate indicated that olivine chlorination might be an attractive means of manufacturing anhydrous magnesium chloride, but the chlorination reaction is not an easy one to carry out on a large scale. The chlorination must be conducted above 1310°C.† to insure complete volatilization of magnesium chloride; yet if the temperature at any point rises above about 1450°C., fusion or partial fusion and agglomeration of the particles will occur. Temperature gradients resulting in fusion of the bed would be extremely difficult to avoid in any fine particle fixed bed more than a few inches in diameter and depth, because of the high heat generation per unit volume and the low effective thermal conductivity of such a bed. The use of a chlorine mass rate high enough to secure any reasonable production of magnesium chloride would also involve an unacceptably high pressure drop through any fine particle fixed bed. Even if chlorination in a fixed bed were possible, charging fresh solids to such a bed and removal of spent residue would be difficult problems because of the high temperature necessary for operation and the presence of poisonous, corrosive gases.

The employment of fluidized-solids techniques *(2)* would offer a solution to the difficulties mentioned above if these techniques could be satisfactorily applied to olivine chlorination. Such techniques are applied to metallic oxide chlorination processes industrially at the present time *(3, 4, 5, 6)*, but the chlorides produced are relatively volatile and temperatures employed are much lower, generally below 1000°C. No instance is known of the use of fluidized-solids techniques commercially in a silicate chlorination, or in production of a chloride under conditions such that the presence of liquid chloride and possible fusion of the particles would be limiting factors in selection of operating conditions. A laboratory program was therefore undertaken to determine whether fluidized-solids techniques could be applied to the chlorination of olivine.

Equipment and materials

The final chlorinator design is shown in Figure 1. The fluid-bed diameter was 30 mm. and the total chamber length was 175 mm. The use of a 75 g. sample of fresh olivine would give an actual bed depth of about 50 mm., leaving the remainder as a disengaging space. It was later discovered that a greater disengaging space would have been desirable after particle density had been reduced as a result of partial chlorination. A small cyclone separtor, also constructed of fused quartz, was hung in the disengaging space as shown in Figure 1 when it became apparent that bed throwout would be a problem. This device was not effective as a cyclone, but it did materially reduce throwout by deflecting splashed solids back into the bed. Actual entrainment of solids was not a serious problem excepting at the highest conversion percentages.

The chlorinator bed was originally constructed using a porous quartz disk for a gas distribution plate as shown in Figure 1. A pressure drop through this disk of about 15 in. of water was experienced during use. This pressure drop tended to mask changes in the pressure drop through the fluid bed, which was only about 3 in. of water in normal operation. Subsequently, a chlorinator having a conical base as shown was substituted. The holes through which gas entered were protected from backflow of solids, by ridges of quartz, but backflow remained a problem with this chlorinator. Otherwise its operation was quite satisfactory; pressure drop through the empty reactor was less than 0.5 in. of water at 0.5 ft./sec. superficial gas velocity.

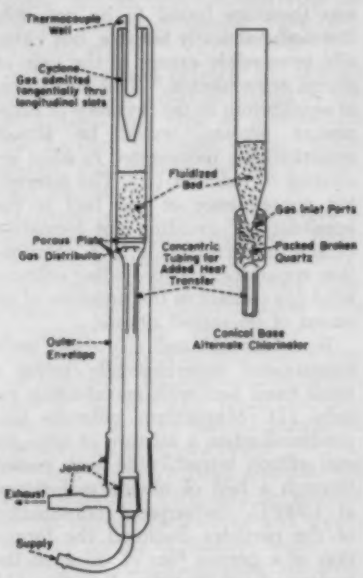

Figure 1. All fused-quartz fluid bed chlorinator.

It was desired that gas entering the fluid bed should be preheated almost to the bed temperature. The concentric section of tubing shown in the figure allowed preheating of gases to within about 100°C. of the solids temperature at the time the gases entered the bed.

The chlorinator was provided with a 40-mm. bore fused quartz envelope to lead exhaust gases down around the outside of the chlorinator and into the base. This effectively eliminated convection currents and permitted dropwise condensation of nearly all magnesium chloride and most of the iron chloride to droplets or crystals. Metal chloride fog formation was avoided by this method of cooling.

Temperature measurement was by means of a Pt-PtRh couple contained in a well extending 75-mm. down into the chlorinator disengaging space.

The entire chlorinator was constructed of transparent-grade fused quartz to minimize the devitrification problem. Experimental runs Nos. 19 to 31 were conducted in a resistance furnace at temperatures up to 1300°C. with an atmosphere of air surrounding the chlorinator outer envelope. Devitrification of only the outer surface of the envelope was quite severe during this period, necessitating renewal of the envelope once and resulting in partial devitrification of the renewed envelope. Only a very thin film of devitrified quartz formed on the surfaces of the chlorinator itself or upon the inner surface of the envelope during the period, provided carbon monoxide was always present at temperatures above 1100°C. All subsequent runs were made in a graphite resistance furnace. Virtually no devitrification of either the chlorinator or its envelope, with one notable exception, occured during subsequent runs in this furnace even though the temperature of the quartz on several occasions reached 1340°C. The heating element of this furnace consisted of a length of 2.5 in. I.D. graphite pipe cut into a 5-turn spiral having a pitch of 2.5 in., and having a 6-in. lead-in section on each end. The furnace was operated vertically with the upper end closed off and the casing gastight. Nitrogen deoxidized over hot copper was supplied continually to the casing, the only exit for the nitrogen being through the chlorinator entry port in the base of the furnace.

Successful operation of the quartz equipment at temperatures where devitrification normally would be severe is ascribed to an inhibitory effect due to the presence of trace, or large quantities, of carbon monoxide. Sos-

† Vapor pressure of $MgCl_2$ need only exceed 0.5 atm. at 1310°C. in accordance with Reaction (1).

man (7) describes instances where carbon monoxide has been reported to inhibit devitrification, and some ininstances where the presence of carbon monoxide apparently accelerated devitrification. No explanation for the observed inhibitory effect is offered.

Following run No. 68 the graphite temperature equalizing sleeve which immediately surrounded the chlorinator envelope in operation was accidentally broken. A new sleeve was inadvertently turned from a piece of graphite that had been used in an electric furnace for the preparation of borides. Following run No. 69 the chlorinator envelope disintegrated almost into powder when the apparatus was cooled below the inversion temperature, although the chlorinator itself was completely undamaged. The only explanation for the extreme devitrification was that a trace of boride tremendously catalyzed devitrification. A new sleeve was turned from uncontaminated graphite with the result that only a moderate amount of devitrification occurred on the following run. The amount of devitrification became less with each succeeding run, presumably as the last traces of boron were disseminated from within the furnace. Sosman reports that boron trioxide will accelerate transformations in quartz from one form to another, but proposes no mechanism.

No evidence of attack on any part of the fused quartz apparatus by chlorine was discovered during the experimental program. Sawn edges remained sharp; the fritted disk was still usable after 25 hr. contact with chlorine-carbon monoxide mixtures above about 1000°C.

During all experimental work the bed pressure drop was accepted as indicative of the quality of fluidization. For the bed depth and material used, it had been observed in prechlorination fluidization experiments that a pressure drop of about 3 in. of water having rapid fluctuations of not more than ± 0.5 in. indicated good fluidization. During the chlorination experimental work it was observed that tapping or shaking the whole chlorinator assembly during a run seemed to improve the fluidization, and less residue was found lodged in the cyclone after runs which had been tapped or shaken. A reproducible shaking motion was obtained through the use of an eccentric cam mounted on a rotating shaft. The motion of a cylinder inside which this cam rotated was transferred by means of an arm and pinions to the clamp which supported the entire chlorinator assembly, thus imparting to it a sinusoidal reciprocating motion.

Silicon tetrachloride in the exhaust gases was instantly hydrolyzed by bubbling through water and retained in the water as colloidal silicic acid. It was weighed as silica after evaporation of the water and ignition to constant weight. Silica so produced was 99.97% volatile when treated with hydrofluoric acid.

Olivine from the southern end of the Twin Sisters was used in all the chlorination work. It had been reduced from boulders to ½ in. by a primary jaw crusher followed by a cone crusher, and from ½ in. to –28 Tyler mesh by means of crushing rolls.

Two samples were prepared for chlorination from the –28 mesh rock. The first was prepared by washing with water in an attempt to remove all material finer than 270 Tyler mesh, after which all material not passing 80 Tyler mesh was rejected. The resulting product was designated Olivine A. The second sample, designated Olivine B, was treated in the same manner as the first excepting that removal of only –400 mesh material was attempted. Screen analyses of the two final products and the starting material are as follows:

	Olivine A	Olivine B	Unwashed –80
On Tyler			
100 mesh	27.8%	1.3	0.73
115	16.9	5.3	2.57
150	16.3	11.5	7.8
200	19.0	21.1	20.4
Pan	20.0	60.8	68.8

Olivine A was used in all successful chlorination runs. It was found through use of the gas permeability method of Lea and Nurse (8) to have a specific surface of 272 sq.cm./g. The particle of average area was found to have an equivalent spherical diameter of 66 μ (between 200 and 250 Tyler mesh). Microscopic examination disclosed that not all extreme fines had been removed in the washing process, but the material could be fluidized easily at gas velocities such that complete solids circulation was obtained without appreciable elutriation of solids.

The equivalent spherical diameter of the average Olivine B particle was found to be 25 μ. Olivine B was not used in any successful chlorination runs because no way could be found to avoid loss of fluidity shortly after commencement of chlorination when using this material.

Experimental observations

Preliminary Fluidization Studies. Extensive prechlorination fluidization tests were run at room temperature on the laboratory bench in order to observe, visually, the nature of the fluidization obtained at various gas velocities. Helium was used in these trials because its properties most closely approximated the properties estimated for the chlorinating gas at 1300° C.

It was found that limited fluidiza-

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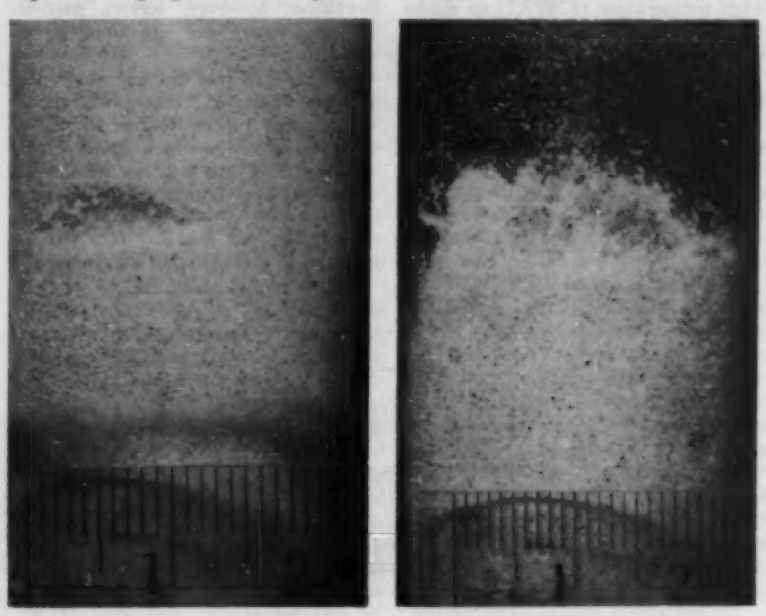

Figure 2. (left) Gas pocket rising through olivine A fluidized with helium at room temperature. (Right) Illustrating violent motion of solids as gas pocket leaves surface of bed. Exposure time 1/700 sec.

continued

tion occurred in beds of both Olivines A and B at superficial gas velocities as low as 0.25 ft./sec.; the calculated velocity for incipient fluidization was about 0.2 ft./sec. The term "limited" fluidization is used because solids circulation within the bed was extremely poor at this gas velocity. Large particles tended to concentrate near the bottom of the bed and small ones near the top. It was necessary to fluidize Olivine A at about 0.4 ft./sec. before solids circulation was sufficient to avoid particle segregation.

Motion pictures exposed at 64 frames/sec. and stills exposed at 1/700 sec. were made of the bed during these tests. The motion pictures showed a phenomenon which has been reported and described many times in the literature: at a gas velocity of 0.4 ft./sec. or above, a sizable fraction of the gas appeared to be passing up through the bed in the form of irregular areas of low-solids concentration roughly analogous to bubbles in a liquid-gas system. These "bubbles" appeared to be constantly changing form as the result of streams and clumps of solids raining down through them. A photograph of one such "bubble" within the bed and another photograph of one bursting at the top of the bed appear in Figure 2.

It appeared that chlorinating gas would pass upward through the mineral bed largely in the form of spaces of low-solids density. Gas within these spaces would be turbulent with good solids-gas contact occurring between the gas and solids either raining down through the spaces or present along their irregular boundaries.

An unknown, but probably small, fraction of the gas reaching the top of the bed would be carried back towards the base of the bed in association with solids in transport. Downward transported solids and gas might re-enter the upward flowing stream at any point due to turbulence and increase in the size of the bubbles as they rise upward through the bed.

This concept of fluidization mechanics therefore involves complete and rapid backmixing of solids, but only limited backmixing of gas. It is in partial agreement with the concept of fluidization mechanics presented by Benenati *(2)* and others. Experimental evidence supports this concept, as it was possible to remove all detectable traces of chlorine in a single pass through the bed from entering chlorinating gas mixtures containing as high as 18% chlorine.

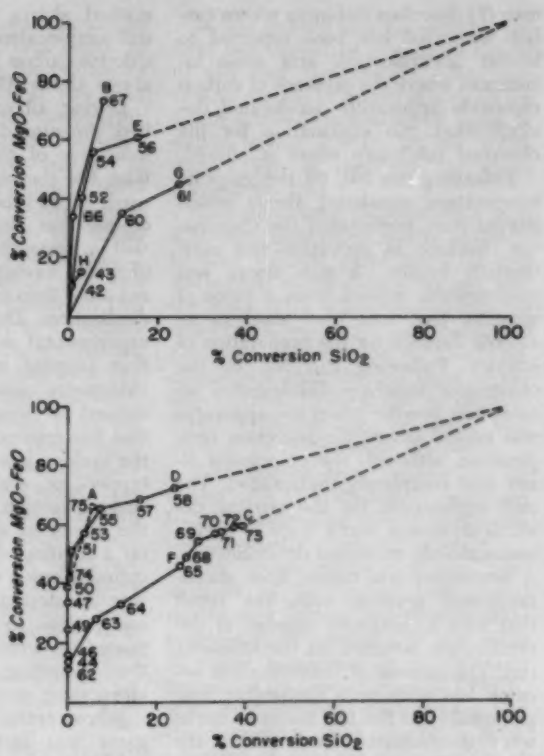

Figure 3. MgO-FeO conversion vs. SiO_2 conversion.

Chlorination Runs Prior to Run No. 41. It was not anticipated that any difficulties would be encountered during chlorination with respect to maintenance of fluidization in the bed other than selection of the correct gas velocity and the use of a sufficiently high temperature (1310°C.) to insure the absence of liquid chlorides. It was expected that the presence of liquid chlorides could be avoided at lower temperatures when chlorinating fresh mineral because of the large fraction of chlorine forming more volatile ferrous chloride when fresh olivine is first chlorinated. Removal of metal oxides from mineral of the analysis given previously should result in no mineral fusion below 1500°C. This was concluded from the work of Bowen and Schairer *(9)*. This upper-temperature limitation appeared to present no problem. Contrary to expectation, however, serious particle agglomeration was encountered in early runs.

Run No. 19 was the first run of the present work. A 50.00 g. sample of olivine was placed within the chlorinator assembly, which in turn was slowly raised into position within the furnace. The sample was fluidized

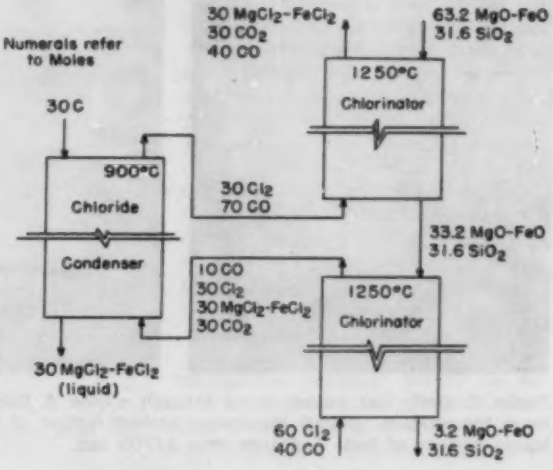

Figure 4. Hypothetical continuous countercurrent chlorinator employing chloride condenser.

first with carbon dioxide and then with carbon monoxide, until the temperature reached 1300°C. At this point chlorine was introduced and flow rates adjusted to give an equimolal chlorine-carbon monoxide mixture at a superficial gas velocity of 0.4 ft./sec. based on the bed operating temperature of 1300°C.

The rate of magnesium chloride formation was extremely rapid during the first few moments of chlorination —small droplets of incandescent magnesium chloride were observed to rain down into the base of the chlorinator. After the first few moments, however, the rate of chloride production dropped almost to zero, as was observed from the rate of chloride accumulation in the base of the chlorinator, and hydrolysis of silicon tetrachloride was observed in the bubbler.

Disassembly of the chlorinator showed the olivine to be adhering to the sides of the bed, with a central hole extending down to the porous quartz plate. The appearance was almost as if gas had been blown through a thick cake batter until the batter suddenly hardened. Individual grains of olivine were still to be perceived in the bed, and the cooled mass could be broken up into the original particles by a spatula, but something had caused the particles to adhere together in the chlorinator shortly after chlorination had begun.

Bed contents were found to contain only 0.028% soluble chlorides, an amount which should have been insufficient to cause sticking. Lumps of bed residue did not disintegrate even when soaked for several days in water, which they surely would have, had the sticking been due to magnesium chloride. Microscopic examination showed no discernible alteration of the olivine crystals or rounding of sharp, angular grains such as would have occurred had the grains been raised to the temperature of incipient fusion.

Following run No. 19 a whole series of runs was made in attempting to find conditions whereby fluidization could be maintained during chlorination. Accuracy of temperature measurement was checked. Pyrometric cone tests run on Olivine A proved that its refractory qualities were as predicted from the data of Bowen and Schairer. The use of dilute gas mixtures was tried, as was chlorination of olivine in admixture with spherical coke particles and Ottawa sand. None of the runs were successful and all showed the same history—a high initial chlorination rate which dropped nearly to zero within one minute. The lower rate was soon accompanied by silicon tetrachloride formation as the chlorinating gas passed upward through the frozen bed in a single channel. This was to be expected from Equations (1), (2), and (3), since available magnesium oxide was quickly removed from the walls of the channel by chlorination.

It was not until run No. 30 that the true cause of failure to maintain fluidization was discovered. Run No. 30 was made using equal parts by weight of −80 + 100 Tyler mesh Ottawa sand and washed residue from run No. 29. A limited amount of conversion had been obtained in run No. 29, made at 900°C. using dilute chlorinating gas.

The bed was fluidized with carbon dioxide and the chlorinator assembly raised into the furnace. All went well until the temperature of the furnace reached 1150°C.; at this point the bed pressure-drop increased by several inches of water and then suddenly fell to a low value, indicating that the bed had frozen and that a single permanent channel had been opened through it. The chlorinator assembly was lowered from the furnace without turning off the fluidizing gas and suddenly, after the bed had rapidly cooled to a red heat, the frozen bed broke up and normal fluidization resumed. The chlorinator assembly was promptly raised once more into the furnace, with the result that loss of fluidization again occurred at about 1150°C. Upon removing the chlorinator assembly and allowing it to cool to a red heat, normal fluidization resumed. This process was repeated a total of four times with the same result each time.

Subsequent examination of the charge showed some small particles of olivine clinging to each other and also to the relatively large, rounded Ottawa sand grains. No chlorine ever entered the chlorinator during this run, and the conclusion was inescapable that loss of fluidization on previous runs was due to the thin film of silica residue formed after initial chlorination. This silica must have reacted with unchlorinated olivine to produce some softening and stickiness, refractory properties of the mineral notwithstanding. The softening apparently began about 1100°C. The reason for the partial breakup of the agglomeration at about 800°C. was of no concern, although the breakup could easily have been due to stress resulting from quartz crystalline inversion.

A technique was developed which made maintenance of fluidization quite easy during chlorination using Olivine A. Gas containing not more than about 6 mole-% chlorine was introduced into a bed of fresh mineral at a temperature of 900°C. After chlorination of only about 6% of the total MgO-FeO content of the olivine, sufficient residue was present on the surface of the particles to permit raising their temperature to 1300°C. without agglomeration occurring within the fluid bed. This technique was not successful with Olivine B, so attempts to use Olivine B were abandoned.

Chlorination Runs Subsequent to Run 41. Data for chlorination runs 42 to 75 are shown in Table 1; conversions obtained are plotted in Figure 3. Gas compositions for the various runs, with the exceptions of runs 42, 43, and 75 were chosen on the assumption that chlorination ideally would proceed countercurrently according to the scheme of Figure 4. At one instant of time during each run, gas and mineral compositions corresponded to the compostions at some point in this hypothetical chlorinator, excepting that carbon dioxide was substituted for the gaseous magnesium chloride which would be present in the chlorinator as visualized. This scheme was used in the hope that numerical values of the factor A/z of Equation (4) would be obtained which might be useful in assessing the applicability of fluidized solids techniques to large-scale chlorination of olivine. It was realized that substitution of carbon dioxide for gaseous magnesium chloride was not completely satisfactory for evaluating A/z, but it was a practical solution to the problem.

The term A/RTz in Equation (4), designated as M in Table 1, was for convenience evaluated instead of the term A/z. This evaluation was made assuming the chlorination rate calculated from residue analyses before and after each run to be equivalent to diffusion rate N_A of Equation (4). The partial pressure of the limiting reactant at the fresh mineral-residue interface was assumed to be zero. The limiting reactant was carbon monoxide in some runs and chlorine in others. An arithmetic mean partial pressure P_{A1} of the limiting reactant was calculated from partial pressures in the chlorinating and exhaust gases. Gas diffusivities required were calculated for gas pairs at 1320°C. using the method of Hirschfelder, Bird, and Spotz *(10)*. Diffusivity of the limiting reactant in the ternary chlorinating gas was then calculated by the method

continued

continued

of Wilke *(11)*. Gas diffusivities at 1315°C. were calculated to be approximately 20-fold their values at room temperature. Values of M could not be obtained in some instances where analytical data were incomplete, or where a mean value of P_{A1} could not be calculated because the concentration of the limiting reactant was found to be zero in the chlorinator exhaust gas.

A detailed discussion of methods used in obtaining analytical data found in, or pertinent to, Table 1 has been omitted for the sake of brevity, but may be found elsewhere *(12)*. Residue analyses were made by standard methods and corrected for chlorination of silica before calculation of conversion, which was calculated on a cumulative basis. The weight of silica in the analyzed dry residue, and the weight of silica recovered from the bubbler after each run, were used in calculating the chlorination of silica and correcting for it. Both the chlorinator supply and exhaust gases were analyzed for chlorine using ultra-violet methods. The percentage of carbon monoxide in the exhaust gas, where required, was calculated from analyses for chlorine assuming the stoichiometry of Reaction (1).

Residue Characteristics. A major aim of the experimental work was to study the residue characteristics as chlorination proceeded—if the rough surface of the residue caused excessive friction between the particles, or if the residue broke away from the mineral particles as fast as it was formed, use of fluidized solids techniques in carrying out the chlorination would be less attractive.

The properties of the olivine, insofar as fluidization was concerned, seemed actually to improve slightly with increasing conversion. This would be expected from a decrease in particle density. No quantitative study was made of fluidization properties as a function of conversion, but visual observation of residues fluidized with helium at room temperatures showed that fluidization was extremely smooth, relative to fresh olivine.

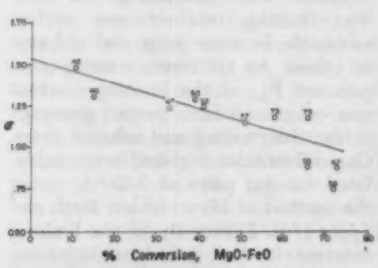

Figure 5. Bulk density of olivine A vs. MgO-FeO conversion.

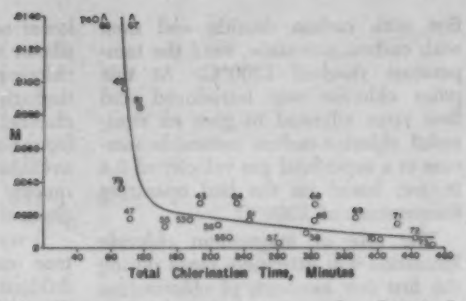

Figure 6. Ease of gas diffusion through silica residue film vs. total chlorination time.

Some of the fines were observed under these circumstances to be agglomerated into larger particles which did not elutriate from the bed. At the chlorination temperature, however, agitation of the bed with the shaker was sometimes necessary to obtain good fluidization, or even any fluidization at all. It is believed that most of the difficulties at the chlorination temperature arose from the presence of small amounts of liquid chloride rather than from roughness of the particles. Different electrostatic conditions may also have been partially responsible.

In the chlorinator, fines tended to elutriate from the bed as increasing conversion reduced their density. Elutriation of partly converted fines became troublesome above 50% metal oxide conversion. Screen analyses made on several residues showed that fines elutriated were originally present in the feed; fines were not generated by the breaking away of residue from parent particles. Chemical analysis of elutriated material provided confirmation of this finding.

The bulk density of Olivine A is plotted as a function of metal oxide conversion in Figure 5. Scatter in the values is attributed to nonuniform packing of the particles between one density determination and the next.

The chlorination residues did have two characteristics at room temperature which became more troublesome as chlorination proceeded. The residues were not readily wetted by pure water; pouring water into a dish containing residue would result in floating powder and bubbles containing dry powder. The addition of a small amount of wetting agent, or a somewhat greater quantity of hydrofluoric acid, greatly facilitated wetting the particles.

The ease with which residue particles accumulated electrostatic charges increased rapidly with conversion. Residues of 60% and higher conversion were almost unmanageable at room temperature, and electrical charges may have been a factor in the increased elutriation of partly converted fines observed during chlorination of these residues. At room temperature, screening or even pouring the residue from one vessel to another became almost impossible. Particles would stick to either metal or glass surfaces and would fly into space. Attempts to brush them would result in their flying through space to the reverse side of the surface, where again they would adhere.

Product Chloride Characteristics. Magnesium chloride was generally observed to condense dropwise in the lower part of the heated section of the chlorinator. It would then run a short distance down the wall of the envelope until it would arrive in a cooler zone where freezing would occur. Chloride so produced was found on analysis to contain at little as 0.29% ferrous chloride, about what would be predicted if solutions of ferrous chloride in magnesium chloride were ideal. Ferrari and Baroni *(13)* report that such solutions are ideal.

Iron invariably formed ferrous chloride rather than ferric chloride. A slightly greater portion of it was formed when chlorinating fresh mineral than was formed otherwise, but a large proportion of magnesium chloride was always found in the product chloride. The small percentage of iron chloride in the exhaust gas resulted in the gas usually cooling below the melting point of ferrous chloride before the dew point with respect to it was reached. A considerable percentage of the ferrous chloride therefore formed an extremely fine powder, some of which had to be removed from the exhaust gas by means of an electrostatic precipitator.

Discussion

The results as plotted in Figure 3 were apparently contradictory. Series H yielded a final conversion of only 15%. Less than 50% of the chlorine in the 8% gas supplied during run 43 of Series H was consumed at an MgO-FeO conversion of only 15%, yet

continued on page 56

Table 1. Data for chlorination runs, 42 through 75

Run No.	Feed*	Series	Chlorinating Gas % Cl_2	% CO	% CO_2	Chlorination time, Minutes At given gas conc.	Total	Gas Velocity†	Temp. °C	Cm SiO_2 in Bed	% MgO-FeO	% SiO_2	Conversion Avg. Rate MgO-FeO‡	Avg. Rate SiO_2‡	N	Residue Density§	Analytical Data Residue % MgO	Residue % Fe_2O_3	Residue % SiO_2	gms SiO_2 in Bubbler
42	75.0	H	5.7	50.7	43.6	97	97	0.3	1225	30.0	10.8	0.6	.00249	.00016	.00955	1.49	48.7	4.62	46.1	0.20
43	57.1 #42	H	5.7	50.7	43.6	90	187	0.3	1225	24.2	15.0	2.9	.00105	.00054	.00277		48.2	4.56	46.7	0.51
44	75.0	D	6.5	46.0	47.5	67	67	0.5	1250	30.4	14.0	0		0			44.5	2.58	52.7	0.00
45	75.0		12			Not Completed. Fluidity lost due to presence of liquid chloride.														
46	75.0	D	6.5	46.0	47.5	36		0.5	1250	29.8										
			16.0	40.0	24.0	18	54	0.5	1250	29.8	15.0	0		0		1.30	47.9	4.75	46.8	0.00
47	53.8 #46	D	18.0	28.0	24.0	45	102	0.5	1250	29.1	33.5	0	.0119	0	.01780	1.24	40.3	4.00	55.2	0.00
	13.2 #44																			
48						Discarded due to Poor Fluidization															
49	75.0	D	7.0	46.0	47.0	34		0.5	1250	30.9										
			13.0	52.0	35.0	27	61	0.5	1250	30.9	24.5	0	.00899	0			45.20	4.74	49.5	0.00
50	37.0 #49	D	18.0	28.0	24.0	10		0.5	1250	29.9										
50	5.8 #47		24.0	44.0	12.0	9	64	0.5	1250	29.9	39.0	0	.0150	0		1.29	40.3	4.36	54.8	0.00
51	50.2 #50	D	24.0	44.0	12.0	9		0.5	1250	31.1										
	6.0 #47		30.0	10.0	60.0	18	113	0.5	1250	31.1	51.1	0.8	.00995	.00113	.00840	1.15	36.5	2.55	60.7	0.27
52	75.0	E	6.0	46.0	48.0	31		0.5	1150	26.0										
52			10.3	52.0	37.7	24		0.5	1240	26.0										
52			18.0	58.0	24.0	5		0.5	1270	26.0										
52			25.7	62.3	12.0	29		0.5	1300	26.0										
52			30.7	10.0	59.3	25	114	0.5	1320	26.0	41.0	2.8				1.25	41.7	2.37	55.6	0.76
53	49.6 #51	D	36.0	16.0	48.0	61	175	0.5	1285	28.9	58.1	3.6	.00368	.00086	.00170		34.5	1.35	63.5	0.64
	1.4 #52																			
54	34.4 #47	E	24.0	44.0	12.0	13		0.5	1260	29.5										
54	21.0 #52		37.4	16.0	46.6	25	145	0.5	1300	29.5	55.6	5.1	.00273	.00257	.00126		35.8	1.90	62.1	1.22
55	34.4 #53	D	42.0	22.0	36.0	54	222	0.5	1280	33.4	66	7.0	.00145	.0024	.00066	0.89	31.2	0.41	68.2	1.83
	15.5 #54																			
56	31.2 #54	E	42.0	22.0	36.0	76	208	0.5	1280	31.2	60.9	15.5	.0031	.0026	.00137		34.1	1.20	64.4	2.57
	21.4 #52																			
57	46.4 #55	D	48.0	28.0	24.0	60	282	0.5	1280	26.1	68.6	15.9	.00097	.0039	.00030		31.8	0.46	67.7	2.60
58	33.7 #57	D	48.0	28.0	24.0	70	315	0.25	1280	30.4	72.1	24.0	.0024	.0041	.00088	0.75	31.3	0.90	67.8	3.67
	19.4 #56																			
59	80.0					-80 Mesh Olivine. Not Completed due to Loss of Fluidity														
60	80.0	G	6.0	46.0	48.0	65		0.5	1300											
			12.0	52.0	36.0	45		0.4	1290											
			18.0	58.0	24.0	71	181	0.4	1290	26.9	34.9	11.8		.0038			46.3	2.85	50.9	2.60
61	52.0 #60	G	24.0	44.0	12.0	64	245	0.5	1280	22.4	44.5	25.0	.00330	.0063	.00161		46.3	2.80	50.6	3.83
62	80.0	F	6.0	46.0	48.0	105	105	0.5	1080	32.0	12.0	0.0	.00256	0			Not Analyzed			0.00
63	69.0 #62	F	12.0	52.0	36.0	51	156	0.5	1285	30.2	28.0	6.0	.0101	.0030			47.0	3.30	49.0	1.93
64	58.7 #63	F	12.0	52.0	36.0	75	231	0.5	1300	26.9	33.0	11.8	.00149	.0021	.00370		46.9	2.60	50.1	1.75
65	52.0 #64	F	18.0	58.0	24.0	30		‡ 0.4	1300					.0042						1.13
65		F	24.0	44.0	12.0	63	324	0.4	1300	21.4	45.7	25.1	.00306	.0045	.00163		46.3	2.20	51.4	2.98
66	80.0	B	6.0	46.0	48.0	45		0.5	1000											
			60.0	40.0	0.0	26	71	0.5	1300	31.5	34.0	0.8	.0190		High		38.5	1.65	59.7	0.005
67	51.8 #66	B	60.0	40.0	0.0	33	104	0.5	1315	27.4	73.0	7.6	.0264	.0052	High	0.975	26.3	1.30	72.3	2.01
68	40.5 #65	C	30.0	10.0	60.0	30	324	0.4	1300	32.0	48.3	26.5	.00231	.00067	.00259		45.9	1.50	52.5	0.37
	24.9 #61																			
69	60.0 #68	C	36.0	16.0	48.0	49	373	0.4	1300	29.2	54.0	29.3	.0026	.0012	.00177		44.3	1.20	54.4	0.74
70	53.0 #69	C	34.0	34.0	12.0	29	402	0.4	1300	26.8	56.5	33.2	.00193	.0044	.00050		44.6	0.95	54.4	1.43
71	48.2 #70	C	48.0	28.0	24.0	21	423	0.4	1300	24.5	56.9	34.5	.00426	.0029	.00144		44.4	1.60	53.8	0.62
72	44.8 #71	C	42.0	22.0	36.0	21	444	0.4	1300	23.3	58.2	37.4	.00149	.0017	.00058		44.6	1.70	53.6	0.36
73	42.9 #72	C	60.0	40.0	0.0	21	465	0.4	1300	21.8	58.8	39.8	.00064	.0038	.00013		45.1	1.80	53.0	0.73
74	80.0	A	6.1	48.0	47.9	36			1000											
			62.2	37.8	0.0	25	61	0.5	1310	31.9	41.0	0.2	.0286	.00006	.0137		41.0	2.30	56.4	0.05
75	56.0 #74	A	30.2	48.8	0.0	32	93	0.4	1315	27.1	66.3	5.7	.0175	.0043	.0036	0.98	30.1	1.60	68.3	1.59

Notes for Table 1

* The first number indicates grams of residue used as feed in the given run. The second number indicates the run from which the residue was derived. The first number indicates grams of fresh mineral used as feed when no second number is shown.

† feet per second at one atmosphere and the run temperature, based on the cross-sectional area of the empty bed.

‡ Units grams chlorine per minute per gram silica in the fluid bed.

§ Bulk density loosely packed, gms./cc.

continued

100% of the chlorine was consumed from 18% gas during run 50 of Series D at a 30% MgO-FeO conversion level. Series B, made using 60% chlorine with 40% carbon monoxide after the initial period, achieved an MgO-FeO conversion of 72% at a silica conversion of only 7%, whereas Series D achieved a 72% MgO-FeO conversion only at the expense of 25% silica conversion and at a much lower chlorination rate. Series A, another high chlorine concentration series, yielded 66% metal oxide conversion at a silica conversion of only 5.7%. Series F and G, in which the supply-gas chlorine concentrations were much less for a given MgO-FeO conversion than in Series A, B, or D, but greater than in Series H, showed excessive silica chlorination and low total chlorination rates at a much lower MgO-FeO conversion level than Series A, B, or D. The MgO-FeO conversion level at which silica chlorination began, and the total chlorination rate, were higher for the Series F and G than they were for Series H. Series C showed that once silica conversion had occurred in quantity, the employment of high chlorine concentrations would not alter substantially either the ratio of MgO-FeO conversion to silica conversion or the total chlorination rate.

A quantitative comparison of chlorination rates made by plotting the term M vs. total chlorination time (Figure 6) provided a hypothesis which appears to explain satisfactorily the various results described above. Microscopic examination of the residues lent further support to the hypothesis.

The value of M varied from run to run primarily as the result of changes in the value of z. The term z, or effective path length with respect to diffusion, would be a function of both the actual residue thickness and the porosity of the residue with respect to mass transfer by gaseous diffusion.

Values of M shown in the figure are somewhat scattered, which may be attributed to a number of factors. Carbon monoxide concentrations were not measured analytically but had to be calculated indirectly. General experimental error, and certainly absolute variation in the values of M, would contribute to the uncertainty of the values. Values of M could not be calculated for runs No. 66 and 67 because the concentration of carbon monoxide, the limiting reactant, became zero at some unknown point in the bed. The value of M for these runs must have been very large, or this would not have occurred.

Figure 7. Photomicrograph of thin sections of residue from run 67 (short chlorination time). Residue layer approx. 0.01 mm. thick, magnification 1000 diameters.

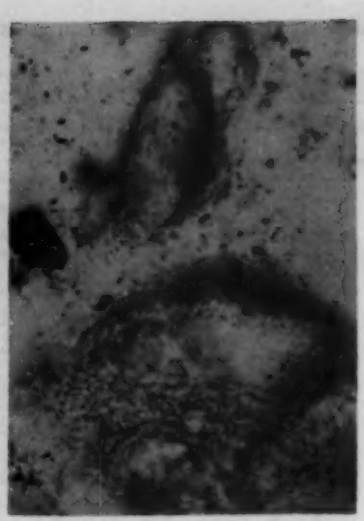

Figure 8. Photomicrograph of thin sections of residue from run 73 (long chlorination time). Magnification 1000 diameters.

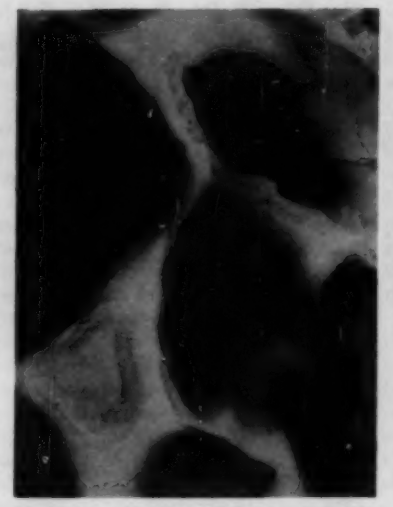

Figure 9. Photomicrograph of whole particles, residue from run 67. Magnification 480 diameters.

Figure 10. Photomicrograph of whole particles, residue from run 73. Magnification 480 diameters.

The important point is that values of M were observed to decrease sharply, independently of all variables other than time, until the total chlorination time reached about 120 min. M was not a function of silica residue thickness resulting from conversion. For example, the actual thickness of the residue layer was much less for run 58 than for run 67, as a result of silica chlorination. This was determined by chemical analysis and confirmed by microscopic examination, yet the value of M for run 67 was much higher than for run 58. The value of M was also demonstrated not to be a function of chlorine concentration; some of the lowest values of M calculated were those for Series C. Gas concentrations used in some of the runs of Series C were as high as those employed in Series B. Series H showed that M was not a function of metal oxide conversion.

The explanation for a large variation in silica residue properties as a function of time alone must involve some basic change in the nature of the silica residue. Sosman *(7)* states

that cristobalite is a form of quartz which is metastable at 1320°C. but which nearly always appears when vitreous quartz or quartz of some crystalline form other than tridymite, is maintained at temperatures above 870° but below 1470°C. The formation of reasonably compact crystals of cristobalite on the surface of olivine particles from quartz of fibrous structure would represent a basic change in the nature of the residue. Crystallization might proceed rapidly once it began, and would be a function of time. If the crystals were compact and prevented access of the chlorinating gas to the unreacted particle, the low values of M and chlorination of silica would be explained. Also, once a relatively impermeable coating had been established, the chlorination rate could become so small that the coating would be maintained by crystallization of silica residue as fast as it was formed regardless of the chlorinating gas concentration employed.

Figures 7 and 8 are photomicrographs of thin sections of residue from runs 67 and 73. The thin sections were made by embedding some of the residue particles in Canada balsam, then sawing and polishing one side of the hardened balsam. The polished surface was cemented to a glass slide and another cut made through the balsam to leave a section, when polished, 0.01 mm. thick cemented to the glass. The end result is a cross-sectional view of the silica residue layer made by the cutting away of the top and bottom of some particles. Figures 9 and 10 are photomicrographs of whole unaltered mineral residue particles of the same two runs. These two runs are indicative of what was seen on microscopic examination of mineral residues from all the runs. They were chosen for illustration because they represent extremes in both the value of M and of total chlorination time.

The silica layer on the particles of run 67 is seen to consist of a large number of extremely fine microlites, the arrangement of which on the surface of the particles shows a faintly fibrous structure with axes of the fibers arranged perpendicular to the surface of the particle. The silica layer on many particles of run 67 was found to be approximately 0.01 mm. in depth. The silica layer on the particles of run 73, in contrast, was much thinner and the microlites were much larger.

A careful check of optical properties indicated that some or all of the silica layer on the mineral residue

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Olivine Chlorination

... an alternative interpretation of data

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Editor's note: In this commentary, the author makes reference to figures in the article "High Temperature Chlorination in a Fluidized Bed" by Johanson & Bengtson.

Sometimes it is possible to develop the chlorination mechanism from data taken to locate operating conditions for a process. This appears to be the case with olivine chlorination. Examination of chlorination residues is very helpful, particularly when coupled with data showing the chlorination history of the residue observed.

Excellent photomicrographs are available. Johanson & Bengtson's Figure 7 shows a clearly defined boundary between unchlorinated and chlorinated material. Figure 9 shows the same effect, but not in a thin section. There is no diffusion of the dark component to the surface to be chlorinated, and the MgO-FeO remains in the lattice until the chlorine and the reducing agent attack it. The path of the attacking gases extends through an increasing depth of unchlorinated silica to reach the receding olivine boundary. The residue of Figure 9 was chlorinated 104 min.

Figure 8 shows a particle that has been under chlorination for a long period of time (465 min.). One would expect to find a large outer zone surrounding the unchlorinated olivine. This is not the case. The dark barrier could be interpreted as a zone which had formed barring chlorination of the interior, but a more likely explanation would be that chlorination conditions existed which caused SiO_2 to chlorinate at a rate sufficient to disappear as the olivine interface moved inwards. This would give the appearance of a thin exterior zone. Removal of SiO_2 in this case was probably by chlorination and by abrasion of the remaining partially chlorinated SiO_2 structure.

Upon chlorination, olivine undergoes a marked density decrease. This is illustrated by Figure 5. If there were no collapse of the structure, removal of the MgO-FeO should decrease the bulk density to 0.7 g./cc. Were the lattice to recrystallize as a dense SiO_2, a bulk density of about 1.1 g./cc. would be observed.

One notes that runs with minimum SiO_2 removal and extensive MgO-FeO removal show a bulk density of

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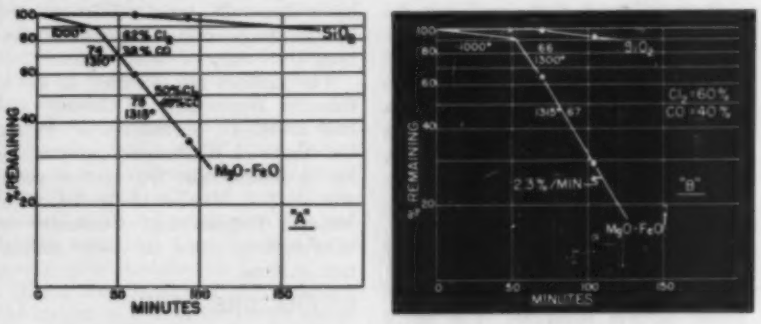
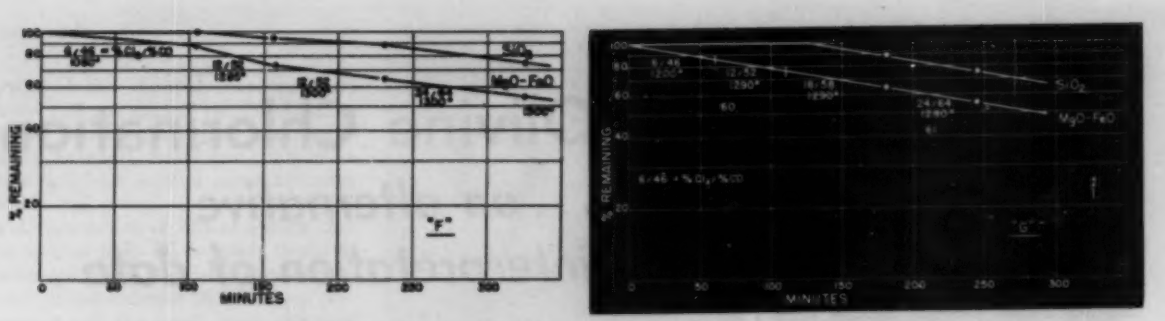


Figures A and B. Olivine chlorination with high Cl_2/CO ratio.



Figures F and G. Olivine chlorination with low Cl_2/CO ratio.

Olivine Chlorination

continued from page 57, col. 3

about 0.75 (Run 58). The scatter of the points makes it difficult to extrapolate, but the residue bulk density appears to be well below the value of 1.1 at 100% MgO-FeO removal.

Upon examining the conversion data of runs A, B, D, F and G (Figure 3), and replotted as log % remaining vs. time, (Figures A, B, D, F, and G), two types of chlorination are evident. Each type has two runs supporting it. In all runs the SiO_2 removal has a steady rate and begins to chlorinate only after a time delay.

Considering first the data at 1300°C., we note that where the Cl_2 partial pressure is low and CO partial pressure high, the SiO_2 chlorination rate is high with a slope nearly parallel to the MgO-FeO slope. Where the Cl_2 and CO are about equal, or the Cl_2 larger, the SiO_2 rate is far smaller than that of the MgO-FeO.

In view of the large thermodynamic difference between chlorination of MgO and SiO_2, it is not surprising to find the SiO_2 rate strongly influenced by the reducing condition present in the bed.

Where the temperature is lowered to 1250°C, the SiO_2 chlorination rate becomes negligible. Run D shows the relation between the chlorination rates. The MgO-FeO rate is affected, but not nearly so much as the SiO_2 rate. Thus to remove MgO-FeO selectively, both temperature and CO concentration should be lowered.

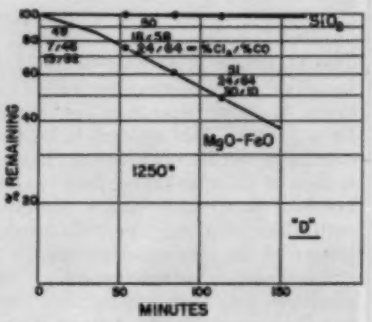


Figure D. Olivine chlorination at 1250°C.

Semilog plotting of chlorination data is frequently found to yield a straight line for porous materials, and also for materials with receding internal boundaries at which chlorination is occurring. Runs D, F and G contain sufficient data to test this relationship.

Conclusions

1. Selective chlorination of MgO-FeO from olivine is possible with control of the Cl_2/CO ratio and temperature. For a Cl_2/CO ratio exceeding 1.0 at 1300°C. MgO-FeO will be stripped out, below Cl_2/CO = 0.33 these materials chlorinate together.

2. Lowering the chlorination temperature affects the SiO_2 chlorination rate more than the MgO rate.

3. No barrier to MgO-FeO chlorination appears as chlorination proceeds. Chlorination ratios of MgO-FeO are 2.3%/min. at 1300°C. and 0.73/min. at 1250°C. These rates are constant for removal of at least 2/3 of the MgO-FeO contained.

High-Temp Chlorination

continued from page 57, col. 1

particles of both runs was comprised of cristobalite. X-ray diffraction studies confirmed this finding, and more important, indicated the absence of any unsuspected compounds.

It is believed that the large decrease in metal oxide chlorination rate observed after about 120 min. total mineral chlorination time was due to recrystallization occurring in the silica layer accumulating on the particles as chlorination proceeded. The fibrous, porous, finely crystalline structure developed initially was apparently replaced by a coarser crystal structure. The latter imposed a much greater resistance to the diffusion of chlorinating gas to the silica residue-unreacted particle interface. The result was a greatly decreased metal oxide chlorination rate and net chlorination of silica, according to Reaction (2), since Reaction (3), could not take place due to the nonavailability of magnesium silicate.

ACKNOWLEDGMENT

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Shale oil ... how soon?

With world energy requirements expected to be six times as great by 2010, the complex engineering involved in extracting shale oil is a vital study for chemical engineers.

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In terms of Union's objectives for an intensive shale program, three areas were of major interest: the first involved the development and demonstration of a practical method for extracting hydrocarbons from oil shale rock, on a commercially significant scale. The second was concerned with the development and demonstration of a manufacturing procedure for converting raw shale oil into finished petroleum products. In the third, the company was seeking to provide engineering and design bases upon which capital requirements and operating costs of a shale oil facility could be reliably estimated.

In view of generally predicted increases in all our requirements for liquid hydrocarbons, matters to be examined are: (1) what is happening to the *cost* of recovering this energy source by conventional techniques; and (2) the sources of liquid hydrocarbons which are available to us. The cost of recovering liquid hydrocarbons by conventional techniques is, of course, increasing. One example of these mounting costs is shown by the increase in record well depths between 8,000 ft. in 1928 and 22,000 ft. in 1956. In 1859, Colonel Drake achieved the first commercial production of oil, at a depth of less than 70 feet. During 1957, the average depth of the wells drilled in the United States was over 4,000 feet. These greater depths involve increases in cost to the producer, which, of course, must be passed along into the marketplace.

One domestic solution to our energy requirements would be, of course, the full-scale harnessing of the tremendous potential of our oil shale reserves, to augment conventional domestic production. Figure 1 compares U.S. and Free World, proved petroleum reserves, as of December 31, 1957, and the most recent U. S. Geological Survey estimate of shale oil reserves contained in what is known as the "Green River Formation". Shale oil reserves of 1.1 trillion barrels are based on 75 percent rock recovery, experienced in the most practical mining scheme to date. Other areas in the world that are known to contain shale oil reserves, of varying quality, are shown in Figure 2. At the present time, shale oil industries exist in Sweden, Spain, and Estonia. In this connection, a recent announcement from Estonia indicated greatly increased shale oil production for use, in this case, as boiler fuel in a large power plant installation.

From the standpoint of marketing the output of a future shale oil industry, Figure 3 illustrates a concept basic to shale oil vs. domestic conventional crude cost (-price) considerations. Prior to convergence of the two cost curves shown, the cost of shale oil declines in fairly discrete steps reflecting technical advances, while the cost of conventional crude oil steadily increases due to inevitably increasing costs of locating, drilling, and producing such oil. At point "A" shale oil and conventional crude oil cost the same. This is, therefore, the point in time at which shale oil enters the marketplace. Because of enormous demand for sources of energy, shale oil will then take its place beside conventional crude oil—as an additional source to fulfill our needs. Beyond point "A", the cost, and parallel price structure, of shale oil will undoubtedly serve as a cost (-price) "umbrella". Production of conventional crude cannot economically proceed above the level of the shale oil "umbrella". The absolute dollar level at which this umbrella effect will occur may fluctuate due to such factors as further technological advance, or inexorably altering economic conditions. Major unpredictable upward shifts in demand due to national emergency could even negate the importance to our economy of cost-price considerations.

continued

PROCESSES

Shale Oil

continued

The effect of this "umbrella" upon the petroleum industry will, however, be significant.

In view, then, of the potential short-term need, due to national emergency, as well as the definitely recognized long-term need for development of this country's oil shale resources, Union has pursued its extensive oil shale research program.

From the scientific standpoint, it is of interest to consider the variety of disciplinary avenues through which the research program has been approached. In terms of unit operations, problems in the areas of material handling, including: conveying; grinding, and classification; solid flow (in this case, oil shale rock pumped upward by a "rock pump"); fluid flow (in this case, hot gases pumped vertically downward); heat transfer (here, *direct* heat exchange); and mass transfer were all encountered. Chemical reactions involved include thermal decomposition, and oxidation.

Figure 2. The areas of the world which contain shale oil reserves of varying quality are shown by the white dots.

The Shale Demonstration Plant, at which mining, rock handling, and retorting phases of our program were pursued, is located in northwestern Colorado. The facility is situated at the point where the east, west, and middle forks of Parachute Creek join to form the main body of the creek, in what is known as the "Piceance Creek Basin", shown in Figure 4. The plant is shown in Figure 5. Rock for the retorting operations was obtained from an experimental underground oil shale mine. The objectives of our mining research program were to develop, as necessary, new mining techniques; to supply typical underground oil shale rock for retorting; and to develop a commercial mining configuration, and firm mining cost estimates. Basically, then, this mine was patterned after the Bureau of Mines' oil shale mine, shown in Figure 6. This method is known as "room and pillar" mining, a concept illustrated more clearly in Figure 7. Rock obtained from this mine was transported first by truck to a primary crusher and then to the valley floor, some eleven hundred feet below, by aerial tram (Figure 8). At the crusher the aerial tram cart dumps crushed shale onto a reserve pile, near the retort, on the valley floor. The oil shale rock is then selectively fed, on a predetermined size-range basis, into the Union Oil retort. Rocks of a major dimension of up to 5 inches can easily be handled by the Union Oil shale retort. This feature lends itself to reduced crushing costs.

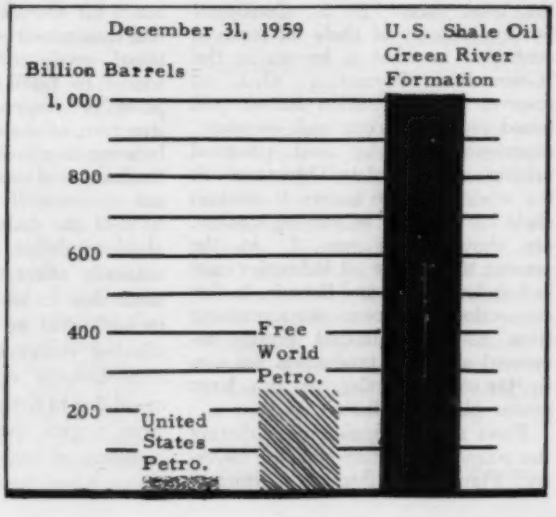

Figure 1. Proven petroleum reserves and estimated shale oil reserves at Green River.

Figure 9 shows the Union Oil retort. The design of the retort is shown more clearly in Figure 10. An important feature of our successful large-scale retort is the application of continuous upward rock feed, and countercurrent retorting. The unique concept of a "rock pump", used to move rock upward from the bottom of the retort, has proved entirely practical, even for extended periods of around-the-clock service. The principle upon which this "pump" operates is shown in Figure 11. Here we see the rock pump successively take on a charge of shale, swing over into the pumping position, pump oil shale rock up into the retort, and then return to the original position, to take on a fresh charge of shale. As the oil shale rock is pumped upward, it is contacted by hot gases pulled down past the rock by blowers. These hot gases result from the burning of residual carbon in the oil shale ash at the top of the retort. The oil condenses on the rel-

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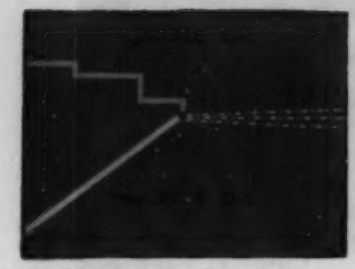
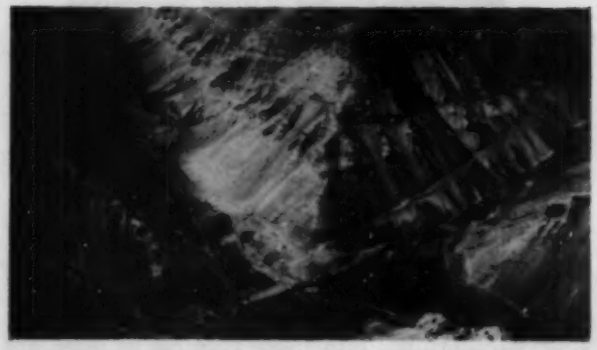
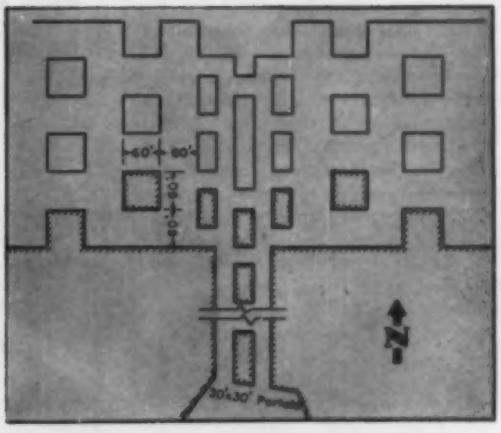


Figure 3. Cost of shale oil vs. conventional crude.





Figures 4, 5, 6, and 7. (Above) The Piceance Creek Basin. (Above right) The Union Oil plant. (Right) Room and pillar mining as used by Union Oil. (Below) Interior of Bureau of Mines mine.

atively cool incoming rock, and recovered oil and combustible gases are withdrawn from the bottom of the retort. Spent oil shale ash continues upward and spills over into a disposal chute. Our retort began operation in March of 1957. Its design rate of rock throughput, 360 tons/day, was reached by early summer of that year. Knowledge gained through our research program has resulted in a series of design modifications, and the development of new operating techniques, which permitted increased throughput rates of up to twelve hundred tons of rock per day. Retort operation at these elevated rates was achieved on fully automatic control for continuous periods of up to six weeks.

At normal room temperature, raw shale oil is below its pour point. Important characteristics of these materials are compared in Figure 12. The refining route we developed for our operations includes coking, and hydrogenation of the coker distillate by Union's process known as "Unifining". This process combination provides control of product pour point, and reduces product sulfur and nitrogen contents to any desired level. While Unifining was originally developed as a refinery process for high-sulfur heavy crude oils, it has won widespread acceptance in this country and abroad for its adaptability to all types of oils. A "commercial shale oil" is produced, by this procedure, which can be readily shipped by pipeline, blended with crude oils, and sold as a high grade crude oil, superior in refining value to most of the world's crude oils.

The use of high-speed electronic data-processing equipment has been a great aid to our refining studies. In our bench-scale experimental shale oil refining work, computation of hydrogen consumption, material balances, component yields, and product distribution, from raw data, were accomplished using an IBM 650. This equipment application afforded increased accuracy, and resulted in significant savings in research manpower.

Finished petroleum products obtainable from shale oil include gasoline, diesel fuel, jet fuel, and kerosene of high quality. In fact, products from shale oil are indistinguishable from their natural petroleum counterparts. Shale-derived jet and diesel fuels, for example, can be manufactured to meet all known military, as well as commercial aviation, specifications. Figures 13 and 14 compare the characteristics of shale-derived jet fuel and diesel fuel with pertinent military specifications.

Figure 8. The aerial tramway used to take ore to the valley floor.

The four major cost factors involved in the commercialization of shale oil are: mining; retorting; upgrading, or beneficiation; and transportation. In mining, our studies confirm that the previously mentioned room-and-pillar mining technique is the most efficient mining method, at least in the "Green River Formation". Refinements of this mining technique will provide cost-cutting areas in addition to what might be gained solely from increased scale of mining operations. In retorting, we have firmly established the technology to design and operate a single retort with a throughput capacity of up to 1700 tons of oil shale rock per day. Further, we believe that a single retort with a capacity of 3,000 tons/day is a reasonable extrapolation. In considering the value of raw shale oil as it exists *prior* to upgrading, technical evaluations, coupled with economic facts which can be brought to bear on the problem, indicate that a price of the order of $2.40-/barrel of 20 plus API gravity raw shale oil, f.o.b. Los Angeles, could be used. At today's distress crude oil pricing, however, this number is unrealistic, and would be closer to $1.80-/barrel. Due primarily to its nitrogen content, it is necessary to convert raw shale oil to the point where it is the equivalent, or superior to, conventional crude oils—we refer to this point, again, as "commercial shale oil"—before a realistic appraisal of actual marketplace price can be made. We must also keep in mind that factors such as interest, profit, income tax or royalties must all be reflected in the final price. It is important to consider recent estimates of shale oil pipelining tariffs, from Rifle, Colorado to Los Angeles, California. Assuming that the material to be shipped from Colorado would be "pipeline-pumpable", we could very easily calculate the effect of increased pipeline capacity. Some tariffs would be required in the first year to return the 7 percent on the investment allowed a common carrier pipeline under the Elkins Act Consent Decree. Tariffs would, naturally, be reduced in later years, as the investment base allowed declines. For instance, tariffs required for a 75-thousand-barrel-a-day case would drop from 56¢/barrel in the first year, to 48¢/barrel in the tenth year. Considering, for example a 25-thousand-barrel-a-day case, and assuming (1) that $2.40/barrel in Los Angeles is correct and (2) that Los Angeles is the logical market for this material, it can be seen that at $1.02/-barrel pipelining charge, raw shale

oil would be worth $1.38, in Colorado. Considering the, currently more realistic, $1.80/barrel price, subtraction of the $1.02 pipelining charge would leave a remainder of $0.78. We seriously doubt that the cost of mining and retorting, by any methods now on the horizon, would permit the extraction of raw shale oil for either $0.78 or $1.38/barrel, and still provide a profit margin sufficient to attract investment capital. Recognizing this, the following must occur:

1. Must have relatively large-scale operation.
2. Must take advantage of low-cost retort-gas energy available for further processing of the raw shale oil.
3. By using the above energy, it is possible to convert the raw shale oil into a high-quality commercial product, and, so, enhance its value to the refiner.
4. Must take advantage of the chemicals available from shale oil. Primarily, income from sales of shale-derived ammonia and sulfur must be realized.

Preliminary figures indicate that, on the basis of 25,000-50,000 barrels/day, delivering semi-refined products to the Pacific Coast or comparable areas, costs compare favorably with similar products made from natural crude oil at prices presently posted for such crudes. But in many cases crude oil is selling for less than posted prices. Under normal conditions this would indicate that with shale oil we are approaching competitive costs.

We are unable to give unequivocal answers on the commercial economics of shale oil at this time for two reasons:

1. Union Oil has not completed its studies on mining and retorting costs.
2. The present price of crude oil, due to world-wide oversupply, is depressed to a point where not only is it impossible to determine just what a competitive price might be, but the production of a large amount of oil from this or any other locality would only augment the present condition of oversupply. Against such a background, it obviously would be impossible to finance by private means a full-scale operation.

Because the study which I have mentioned above, performed for the National Planning Association, reflects areas of interest which point to problems of a future shale oil industry, and to problems which could be solved by the creation of such an industry, I should like to quote again from their report—this time from the conclusions section, dealing with implications for a national energy

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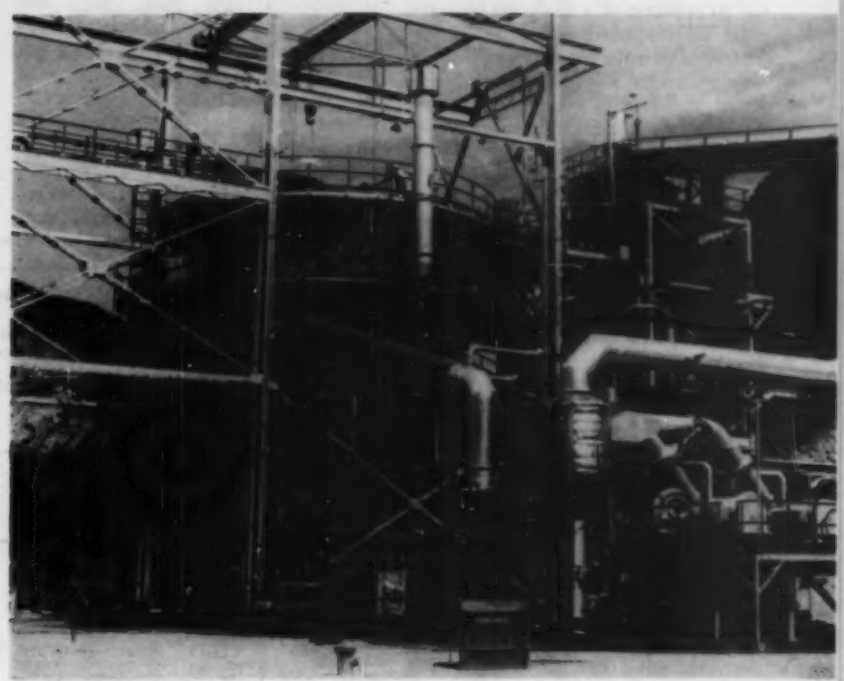

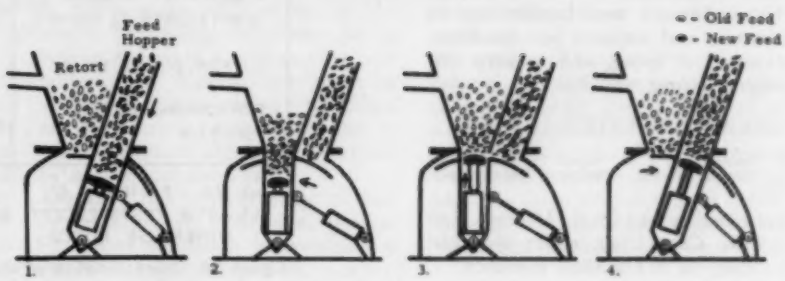

Figures 9, 10, and 11. (Above right) The Union Oil retort in use. (Above) Schematic diagram of the retort. (Right) Schematic diagrams of the operation of the "rock pump" concept created by Union Oil.

Shale Oil

continued

policy. Their statement is:

". . . Any national policy concerned with assuring an adequate energy base must therefore consider energy in each form; technical research and development in improved methods of finding, winning, processing, transporting, and consuming energy must advance on a broad front. Specifically, this includes each of the conventional fuels, oil from shale and coal, as well as nuclear energy and the other, even less conventional, energy forms such as solar energy and controlled thermonuclear fusion.

". . . The implications of a domestic synthetic liquid fuels industry—whether based on coal or on shale oil—are relevant in determining overall energy policy. . ." End of quotation.

We, of Union Oil, believe that in any realistic appraisal of such an energy policy, one cannot overlook recognition of one of the conditions essential to creation of a shale oil industry —the much-needed enactment of depletion allowance tax treatment equitable with that afforded to producers of oil and gas by conventional techniques. The present depletion allowance pertaining to oil shale rock means absolutely nothing, because it is based on the value of the rock itself, which has *no* value until beneficiation has been achieved and oil has been obtained from the rock. Favorable congressional action on this matter will be a step toward the creation of this new potential industry based, primarily, on advanced American technology.

We have seen that energy consumption is expected to expand to very high levels. We are potentially secure in our petroleum needs, however, by virtue of our tremendous oil shale reserves and by the availability of recovery methods such as the one I have outlined. I submit that we, in the engineering and scientific professions, have an unparalleled opportunity to provide the technology to meet this ever-increasing energy demand. The bases of the urgency to continue to do this within our own borders are to maintain and improve our American standard of living, and to keep our country strong and free.

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Presented at A.I.Ch.E. Meeting, Salt Lake City, Utah, under the title, "Progress in Oil Shale Research."

CHARACTERISTIC	RAW SHALE OIL	SANTA MARIA VALLEY CRUDE OIL
GRAVITY, °API AT 60°F	21	14
POUR POINT, °F	+90	+20
VISCOSITY, SSU AT 122°F	175	215
SULFUR, % BY WEIGHT	0.7	5.0
NITROGEN, % BY WEIGHT	1.8	0.6
COKE YIELD, % WT OF TOTAL FEED (TYPICAL)	10	15

Figure 12. Comparative characteristics of shale oil and conventional crude oil.

CHARACTERISTIC (a)	FEDERAL SPECS (b)	SHALE-DERIVED JP-4 JET FUEL
AROMATICS, VOL %	25 MAX.	17
FREEZING POINT, °F	-76 MAX.	-78
HEAT OF COMBUSTION, ASTM 1405	18,400 MIN.	18,634
SULFUR, MERCAPTAN, WT %	0.005 MAX.	0.0002
SULFUR TOTAL, WT %	0.4 MAX.	0.01
NON SPECIFICATION TESTS		
NITROGEN, TOTAL	—	0.05
CFR COKER MERIT RATING	(c)	72

(a) ASTM TEST EXCEPT WHERE OTHERWISE NOTED.
(b) MIL – F – 5624 C
(c) NOT CURRENTLY SPECIFIED ANTICIPATE 50–55 MINIMUM TO BE ESTABLISHED.

Figure 13. Characteristics of shale-derived jet fuel.

CHARACTERISTIC (a)	FEDERAL SPECS. (b)	SHALE-DERIVED DIESEL FUEL
CETANE NUMBER, D-613	47 MIN.	55.2
POUR POINT, D-97, °F	0 MAX.	0
CLOUD POINT, D-97, °F	10 MAX.	-4
KINEMATIC VISCOSITY, CENTISTOKES @ 100°F	2.1 – 6.0	2.3
SULFUR, D-129, WT. %	1.00 MAX.	0.01
CORROSION, FED. STD. 791-5313	NO. 1 ASTM MAX.	1 (a)

(a) MIL – F – 16884 C
(b) ASTM TESTS EXCEPT WHERE OTHERWISE NOTED

Figure 14. Characteristics of shale-derived diesel fuel.

Circulating Magma Crystallizers

Performance characteristics and operating details of magma crystallizers, including scale-up problems, recent design concepts, and applications details.

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ALTHOUGH circulating magma crystallizers have been widely and successfully used for many years, there has been little published regarding performance characteristics. There are many possible methods of classifying the various types of crystallizers including:

1. Whether batch or continuous
2. By method of producing supersaturation (cooling only, cooling with evaporation, evaporation only, reaction, etc.)
3. By method of cooling (vacuum or surface cooled).
4. Whether agitated or unagitated
5. Whether discharge solids are classified or not
6. By manner in which growing crystals are brought into contact with supersaturated liquor.

For the purposes of this article, method 6 above will be employed, since equipment can be more easily classified by *operating* characteristics and *product* characteristics with this method than with the others. Under this system of classification almost all large tonnage commercial crystallization equipment in the United States today may be considered under the three following headings:

a. Unagitated tank crystallizers
b. Circulating liquor crystallizers
c. Circulating magma crystallizers.

Each of these classifications is discussed in greater detail below—the first two somewhat briefly for purpose of identification, and the last one in more detail since it is the subject of this paper.

Definitions

Unagitated Tank-type Crystallizers. These are the most numerous and have been employed to crystallize practically every product at one time or another. As usually employed, they consist of an open tank into which unsaturated or saturated solution is charged and in which precipitation of a crystal crop occurs by surface evaporation and cooling.

Supersaturation is generated at the surface of the tank by evaporation and cooling and at the walls by cooling. A slow circulation of liquor takes place, caused by specific-gravity differences due to temperature and concentration gradients. As this circulation takes place, supersaturation is discharged from the liquor onto crystals on the walls and bottom of the tank.

Circulating Liquor Crystallizers. In crystallizers of this type supersaturation is imparted to the liquor in one part of the equipment by cooling, boiling, or reacting. The liquor is then conducted to another part of the crystallizer where it gives up this supersaturation to the growing crystal or crystals and is then circulated back to be supersaturated again. The Oslo or Krystal unit is an example of this type of crystallizer. Another example is the equipment used to grow large single crystals for electronic purposes. This type is not always found in the pure form since it is usually difficult to attain complete separation between the crystals and the circulated liquor in commercial sized units.

Circulating Magma Crystallizers. This classification includes all those in which the growing crystals are circulated intentionally to the zone of the crystallizer where supersaturation is being created. The crystals may be transported to this area by mechanical or hydraulic means. The zone of generation of supersaturation may be the boiling surface in a vacuum-type crystallizer, the water-cooled tubes or shell of a surface-cooled crystallizer, or the reaction zone in a unit in which supersaturation is being created by a chemical reaction.

Although this classification is commonly associated with the tangent-inlet forced-circulation body which is the most important present commercial application, it is a broad classification and includes all mechanical crystallizers such as the Swenson-Walker, Wolfe-Bock, Votator, etc. It includes salting evaporators of the calandria and agitated calandria types as well as sugar strike pans. It also includes commercial crystallizers of the continuous and batch vacuum-cooling type.

The differences among the three classifications listed above can best be illustrated by graphing the basic driving force (supersaturation) vs. time for each of the three types listed (Figure 4). The unagitated tank crystallizer has, in general, a high supersaturation level in the mass of the solution at the start of the batch and this level varies with heat transfer and seed surface greatly during the batch. The supersaturation of this mass vs. time is shown on Figure 4. At the end of the batch this level is generally quite low.

The second line on Figure 4 shows changes in the supersaturation level in a gallon of liquor as it is circulated through a circulating liquor crystallizer. First flashing, or cooling, of the liquor generates supersaturation to about 5-7°F. (lower in some cases). This liquor is then transported (horizontal line in Figure 4) to a seed bed where desupersaturation occurs (line of decreasing slope). Mixing of hot unsaturated feed unsaturates the liquid; then the cycle is repeated. The dotted line indicates reduction in supersaturation due to nucleation during transfer.

The circulating magma crystallizer (a vacuum unit is shown on the graph) generates about the same level of maximum supersaturation as the circulating liquor type, though in recent designs the tendency has been to reduce this value several fold by higher recirculation rates as illustrated by the comparison between the curves for

continued

Crystallizers

continued

the forced-circulation and draft-tube units in Figure 4. The presence of the crystal magma at the zone where supersaturation is created immediately utilizes this driving force, and the real supersaturation level is therefore considerably lower than either of the other types. The actual level is shown by the dotted line on the graph.

Circulating magma crystallizers, including those enumerated above, have been in common use for a long period of time. In the past, equipment of this design produced a crystalline product that varied widely both as to size and uniformity. In recent years increasing importance has been attached to the ability of this design to produce uniform crystals of many materials in the 20-40 mesh size range because of the reduction in dusting and in caking in storage. Also, such a product is more readily washed free of adhering mother liquor, and since it can be filtered or centrifuged to a lower moisture content, the heat requirements for drying are reduced. Therefore, it is of interest to consider what factors in the design and operation of circulating magma crystallizers will tend to create a product with the desired characteristics.

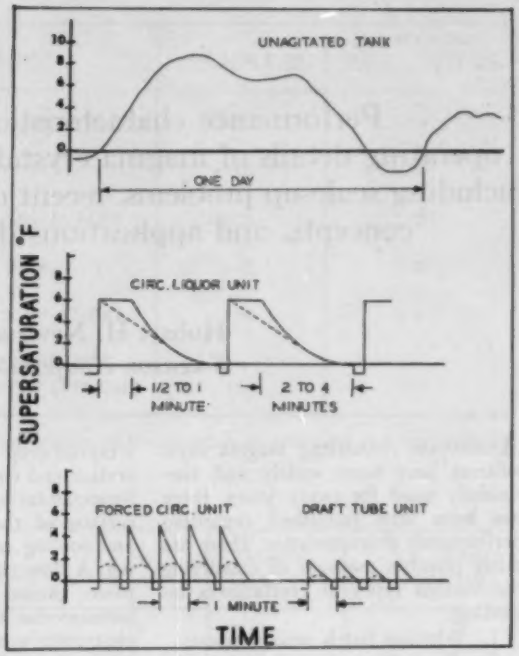

Figure 4. The basic driving force (supersaturation) vs. time for each of the three types of crystallizers listed.

Crystallization theory

As an introduction it is desirable to review briefly the basic theory of crystallization. This will be presented in an abbreviated form since much has been published regarding this. Figure 1 represents the solubility curve of a typical inorganic salt of normal solubility. Each point on this solubility curve represents equilibrium conditions in a saturated solution in contact with solid phase salt. Early observations by Ostwald *(1)* and experimental work by Meyer and Isaacs *(2)* postulated that under some conditions it was possible to have a "metastable supersaturation" range in which crystallization may occur on existing seed crystals without spontaneous nucleation in the bulk of the solution. It was thought that further cooling into the "labile" area would result in spontaneous nucleation in the bulk of the solution.

Figure 1. Solubility curve of a typical inorganic salt of normal solubility.

The application of such a concept in commercial crystallization is useful and has frequently been employed. The work of many investigators, however, has shown that this concept is not exact and in practice it can be seriously misleading unless its limitations are understood.

If a solution is supersaturated even a small amount, spontaneous nucleation will generally occur if a sufficiently long waiting time is allowed. Once nuclei are present, the supersaturation is dissipated at an accelerating rate. This "time decay" has been reported by Preckshot and Brown *(3)*. The level of supersaturation which can exist for any given time is inversely proportional to the mechanical stimulus or shock in the solution. The entire metastable field can be made labile by producing sufficient mechanical shock *(4)*.

The quantity of seed crystals present, their size, and the speed of agitation in the system have been shown to influence the rate of formation of new nuclei by Ting and McCabe *(5)*. It has been suggested in fact that the size solubility relationships alone *(6)* may account for the metastable region.

The presence of impurities as a factor in both increasing and decreasing the tendency to nucleate supersaturated solutions has been shown by many investigators.

Temperature has been shown to affect both growth and nucleation by its combined effects on concentration, surface tension, interfacial tension, and viscosity.

The most useful way to regard the area of metastable supersaturation is that as supersaturation is generated to progressively greater degrees in any given crystallizer, the rate of nucleation in the bulk of the solution increases until at some point, which usually lies between 1 and 5°F., supercooling with common inorganic salts, mass nucleation of the solution occurs. Graphically, this can be depicted as in Figure 2.

The importance of understanding the effect of nucleation in crystallizer design cannot be overemphasized. The weight of the average particle produced, and hence its size, is the total weight of product produced divided by the total number of particles in the product.

To illustrate this point further, let us assume that the nuclei produced in a commercial potassium chloride crystallizer are 140-mesh in size. This assumption is purely arbitrary but corresponds to about the smallest discrete particles seen in many commercial units. No doubt the actual nuclei formed are smaller than this but in

their environment quickly attain this size. When 1 lb. of these 140-mesh particles are grown, the final weight of the product is shown in Figure 3.

To attain a 40-60 mesh particle, the final product must have 15 to 75 lb. of material deposited on the original pound of seed. To get a 30-mesh product, 200 lb. must be added, whereas to attain a 20-mesh crystal, 588 lb. are required, and to reach 14-mesh, 2860 lb. must be added to the original pound of seed. These figures emphasize the necessity of controlling nucleation, since if 2860 lb. of a 14-mesh particle size are required, only one pound of nuclei can be allowed to grow.

Design

Regardless of type, a crystallizer may be thought of as a device in which an environment can be created conducive to the formation of crystals of a desired size or shape. In this environment must be present a driving force to produce crystallization (supersaturation) and a crystal birth rate which can be thought of as the rate of nuclei formation, plus the particles formed by attrition, plus the rate of seed crystal addition, minus the rate of fines destruction. Since the designer can deal with this problem only on the macro scale, application of the theoretical principles described is, in practice, translated into control of the following major variables:

1. Reducing the level of supersaturation to correspond to low rates of nuclei formation.
2. Maintaining adequate seed crystals both as to size and quantity upon which the deposition of the generated supersaturation may take place. (This can be measured in terms of retention time of the product crystals.)
3. Contacting the seed with the supersaturated liquor as soon as possible to avoid losses due to time decay.
4. Removing excess nuclei or fine crystals as soon as possible after their formation.
5. Minimizing mechanical stimulus and attrition which promote unwanted nucleation.
6. Providing, so far as possible, conditions of temperature, viscosity, interfacial tension, surface tension, and impurities which favor the growth of the desired product.

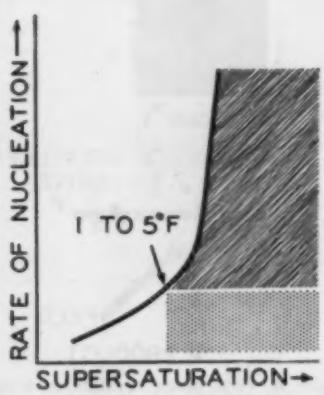

Figure 2. Rate of nucleation curve showing point of mass nucleation.

Application of these general principles to the design of specific items of equipment has, in general, followed a stepwise examination of the practical range for each variable when holding the others within previously understood limits.

Early investigations showed that forced or internal circulation in early circulating magma machines was so small that labile supersaturation was created, and that improvement in calandria, forced-circulation evaporators and forced-circulation crystallizers could be obtained if the flashing at the boiling surface was reduced to the order of 3-8°F. This reduction brought additional benefits such as more uniform vapor release and reduction of wall salting due to less vigorous boiling action.

Parallel experimentation with surface-cooled crystallizers showed that the delta T in the cooler should be approximately 3-15° between the cooling surface and the liquor being cooled to minimize high levels of supersaturation of the liquid at the tube wall interface, which is conducive to massive salt formation on the cooling surface. Further reduction of supersaturation without other modifications is of questionable value, however.

In many of the early forced-circulation crystallizers and batch crystallizers the speed of the pump or propeller was from 400 to 1750 rev./min. At such speeds severe attrition and mechanical stimulus to the supercooled magma occur and excessive nucleation takes place.

A common fault of many early vacuum units was failure to elevate sufficient quantities of solids to the boiling surface for relief of generated supersaturation. Experimentation with forced-circulation and calandria machines indicates magmas of 10-30% apparent settled solids are frequently required.

The improvement in results from the adjustments in design and operation just discussed is substantial *but whenever supersaturation is produced in commercial equipment, there is a finite nucleation rate in the presence of these conditions which is characteristic of the material, the hydraulic regime, and level of mechanical stimulus, tending to limit the size of the average product such as potassium chloride, sodium chloride, potassium fluosilicate, 5 and 10 mol borax, etc., to around 30-60 mesh in FC machines. To increase product sizes beyond this point requires careful attention to solids movement paths in the vessel and methods of excess nuclei destruction.*

A recent circulating magma design

One method of achieving improved performance with the circulating magma crystallizer is by employing the draft-tube baffle (DTB) configuration.

The draft-tube baffle crystallizer as presently designed consists of a closed vessel with a vertical draft tube surrounding a propeller located at or close to the bottom of the unit. The propeller circulates liquid and crystals from the bottom to the top of the vessel. In the outer shell of the vessel is a partitioned settling area to allow regulation of the magma density and control of nuclei removal.

This equipment is an improvement over prior designs because it brings growing salt to the boiling surface, where supersaturation is most intense, more effectively and more frequently than any of the earlier units except, possibly, the smaller mechanical crystallizers. It maintains a large internal circulation within the body to reduce supersaturation at the boiling surface and bring solids in a positive path to the surface irrespective of size. This internal circulation is achieved against extremely low heads of a few inches

continued

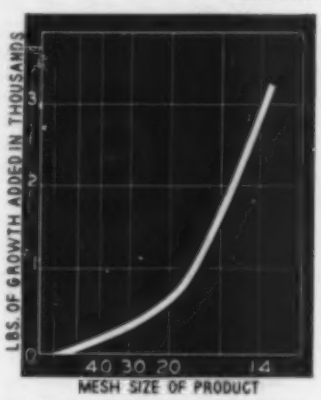

Figure 3. Final weight of product when 1 lb. of 140-mesh particles are grown.

Crystallization

continued

of water and thereby requires much less horsepower than any type of external circulating loop. When correctly utilized it has sufficient seed surface present at the boiling surface to sponge up supersaturation effectively and minimize nuclei formation. The internal velocities are easily sufficient in all areas to suspend the largest salt intended to be handled in the equipment. Crystal products from machines of this type can readily be grown from 30-14-mesh in size, although this is not a limitation.

One of the most important characteristics of this design is the uniformity of the product. This is easily understood by recalling the extremely small number of seed crystals required to maintain a *uniformly agitated suspension* of 30-14-mesh product crystals.

A case history

The improvement in product size, product uniformity, and salting cycles which can be achieved by application of the factors discussed can best be illustrated by a specific example. Let us examine the operating conditions of an outdated three-stage continuous vacuum crystallizer producing KCl by evaporative cooling. The first stage crystallizer body is illustrated in Figure 6 and is 10 feet in diameter with a 60° cone bottom and a dished top head. The liquid volume is about 5200 gal. and the feed rate on a continuous basis is about 550 gal./min., giving a nominal retention of liquor and crystals of about 10 min. The feed is injected just in back of the off-center propeller which agitates the vessel contents.

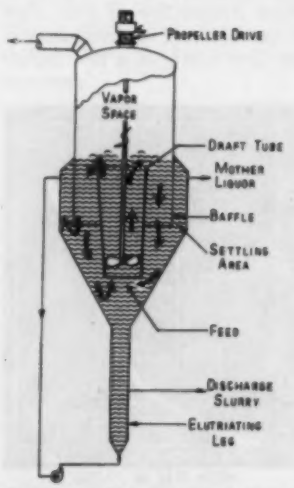

Figure 5. Cross section drawing of a draft tube crystallizer.

The cooling occurring in this first-stage body causes a crystal yield of about 3% by weight of the liquor, and the crystals with the cooled mother liquor are pumped out of the cone bottom and transferred to the next stage or to the separation equipment.

Studying the details of this operation as they affect crystal size and uniformity, the following points are noted:

1. The hot feed is brought into the body at a point not sufficiently submerged to prevent boiling in the inlet pipe. Violent flashing at this point cools the feed to such an extent that the metastable zone is exceeded and spontaneous nucleation results.
2. The discharge stream from the propeller being directed horizontally is not effective in carrying crystals up to the boiling surface for growth. This has two adverse effects—since the salt does not get very near the surface, it is not subjected to the action of the most highly supersaturated liquor and thus growth is not as rapid as it might be. Also, this means there is little salt present at the surface to sponge up the supersaturation being generated and consequently this is likely to cause spontaneous nucleation.
3. Since the natural magma resulting from cooling the feed is only about 3%, there is not sufficient seed surface present in the body to hold supersaturation levels down even if the propeller were able to circulate it all to the surface.
4. The quantity of solids and hence the residence time of the solids in the body is too short for growth to 20-30 mesh.
5. Propeller speed is high (400 rev./min.) giving undesirable nucleation by mechanical stimulus and attrition.
6. Insufficient circulation of liquor to the surface causes this to flash through too wide a range, creating too high a level of supersaturation. This both increases nucleation and causes boiling to be more violent, splashing liquor high up on the body walls. Salting cycles of one day are common on first stage operation.

The screen analysis of the product from the old units in such an operation is shown in Table 1. Essentially this is a 60-mesh particle of relatively wide distribution with many fine crystals in the −65 +200 mesh range and an absence of material larger than 40-mesh.

Changes in circulating magma crystallizer design to produce a larger and more uniform KCl product included the following:

1. Increasing the magma density from 3 to about 30% and retention of the solids in the body from 10 min. to 3 hr.
2. Reducing the flash at the boiling surface from several degrees to 1° F.
3. Directing the solids movement paths to the boiling surface.
4. Reducing the speed of the agitation from 400 to 125 rev./min.
5. Providing for nuclei removal and destruction.
6. Submerging the feed inlet to prevent flashing before mixing with the circulating liquor in the crystallizer body.

The embodiment of these improvements is shown in Figure 5. The actual volume of the unit is 8,000 gal., but due to the thickening provision of the settling section the magma retention can be increased to 3 hr. The large propeller in the center of the vessel directs slurry movement to the surface and reduces the flashing at the surface to 1° F., which minimizes supersaturation and gives a moderate boiling action well distributed over the surface. The fine solids leaving with the mother liquor are smaller than 60-mesh and represent an insignificant fraction of the total production. A typical screen analysis for the product is shown in Table 1

Figure 6. First stage crystallizer body in a three-stage continuous vacuum crystallizer.

under the heading "New DTB." This material is extremely uniform and shows an absence of either fines or oversize material. Salting of the body walls is almost eliminated and the equipment is shut down about once a month for inspection, although no substantial salt deposits are present within the body.

Scale-up of equipment

Irrespective of type, the following features are desirable in successive installations of various sizes.

1. Duplication of wanted features.
2. Avoiding repetition of undesirable features
3. Obtaining certainty of results
4. Adaptability to pilot plant for exploration and demonstration.

Scale-up of results in a circulating magma crystallizer in general, and the evaporative type in particular, has always been difficult. Although supersaturation levels are low as created at the boiling surface, with temperature and magma levels adjusted to be equal in different units, forced-circulation crystallizers of different sizes have not always produced equivalent results. It is evident that in the same environment a crystal will grow and behave in the same way. If the factors which control crystal growth are equal but equal results do not appear in two different units, then crystallizer characteristics and, therefore, the rate of nuclei formation, must be different.

The crystallizer characteristics referred to embrace all the hydraulic features of the crystallizer which include the following:

1. Velocities (mass and point)
2. Solids movement paths
3. Residence time at the zone of generation of supersaturation
4. Secondary circulation and actual supersaturation levels
5. Level of mass supersaturation at equivalent points.

For purposes of analysis let us direct our attention to the most important of the commercial equipment, the tangential inlet forced-circulation machine and the DTB machine operating under vacuum.

The variables which affect flow patterns in a vacuum crystallizer are of four types. First are the linear dimensions which define the boundary of a crystallizer. Since in most cases various sizes of the same basic design are being considered, one major length can be used as the characteristic length and the other linear dimensions then become ratios of it. Since these ratios will always have the same value in geometrically similar units, they have been omitted from this discussion. The mathematical definitions which follow include only groups containing the elements of force, time and length as a characteristic length.

Second, the kinematic and dynamic characteristics of flow such as power consumed, velocity, and gravity must be considered. In the forced-circulation unit the inlet velocity which sets the body of fluid in motion supplies the energy to maintain the flow pattern against the viscous and gravitational forces. In the draft-tube unit this motion is supplied by the propeller of diam. D at speed N rev./sec.

The third major class of variables are the fluid properties such as density and viscosity.

In boiling liquids (as in the FC crystallizer) the motion is affected greatly by the character of the vapor release. The character of this release changes with temperature, boiling point elevation of the solution, and superheat of the liquid. The fourth major variable then which must be included to describe fluid motion in a boiling vessel is the submergence S. The term is used here to denote the submergence required to suppress vapor formation in the superheated liquid delivered to the vessel, or boiling surface in the case of the DTB.

By using techniques of dimensional analysis in examining typical samples of the equipment under consideration, the relations in Figure 7 may be derived.

The term on the left in each case is usually called the power number and is a dimensionless expression of the Newtonian inertia force. This term characterizes the basic flow pattern.

The first term on the right is the Reynolds number and characterizes the effect of viscosity. The second term on the right is the Froude number and incorporates the effect of gravitational forces. The third term is a dimensionless ratio of the submergence to the characteristic length.

Forced Circulation Body

$$\frac{\Delta P g_c}{V^2 \rho} = \phi\left(\frac{DV\rho}{\mu}, \frac{V^2}{Dg}, \frac{D}{S}\right)$$

$$\frac{\Delta P g_c}{V^2 \rho}, \frac{Pg}{\rho N^3 D^5} \quad \text{Power No.}$$

$$\frac{DV\rho}{\mu}, \frac{D^2 N \rho}{\mu} \quad \text{Reynolds No.}$$

$$\frac{V^2}{Dg}, \frac{DN^2}{g} \quad \text{Froude No.}$$

Draft Tube Body

$$\frac{Pg}{\rho N^3 D^5} = \phi\left(\frac{D^2 N \rho}{\mu}, \frac{DN^2}{g}, \frac{D}{S}\right)$$

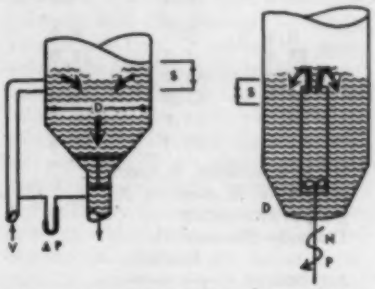

Figure 7. (Left) a forced circulation body. (Right) a draft tube body.

Table 1

	Old Units	New DTB
+14		0.0
+20		84.4
+28	0.1% cum.	94.2% cum.
+35	1.7	96.8
+48	18.7	99.6
+65	59.9	
+100	84.2	
+150	92.4	
−150	7.6	

When viscous forces and gravitational forces are both important (as in a forced-circulation body when vortexing and toroidal circulation exist) then N_{Re} and N_{Fr} are important. In boiling FC machines, particularly at high temperatures where submergence is high, the ratio D/S must be included.

Since there is no useful or even generally accepted mathematical relation describing crystal growth, the only obvious way to produce identical crystals in two different units of equipment is to produce identical environments for crystal growth; that is, for any one material to yield a product in a large-scale machine equivalent in characteristics to that produced in a test unit, there must be created in the large equipment:

1. The same driving force
2. The same seed surface character, i.e., size, magma
3. The same secondary factors of environment (i.e., temperature, viscosity, etc.)
4. The same hydraulic regime defined as
   a. The same power number
   b. The same Reynolds number

continued

Crystallization

continued

c. The same Froude number
d. The same submergence ratio D/S
e. Geometric similarity

If these conditions are met, it can be assumed the growth rate and the rate of nucleation will be identical in the model and prototype and therefore the same product characteristics can be expected.

For most of the cases discussed it is impossible to produce the same hydraulic regime in different-sized vessels with the same solution and crystals. This is especially true if the Froude number is important, and is because the Froude number varies as the square of the velocity, whereas the Reynolds number varies as to first power of the velocity and the power number varies as the $^1/_{\text{square of the}}$ velocity. These same conclusions were reached by previous studies *(7, 8)*.

By utilizing a circulating magma crystallizer that is so designed that the controlling dimensional groups can be made equivalent in different-sized units, the problem of scale-up can be reduced considerably. In the forced-circulation unit, vortexing and toroidal circulation occur and, therefore, the Froude number and submergence ratio are important, whereas in a draft-tube crystallizer, with directed solids movement paths and proper baffling, vortex formation is eliminated and the Froude number and submergence ratio become unimportant. The characteristics of the draft-tube system are such that equivalent hydraulic regimes can be produced in large equipment with the same power number at substantially different Reynolds numbers, providing the propeller can operate at speeds low enough to prevent mechanical stimulus and attrition of the product and the internal liquid circulation can be reasonably approximated with respect to the velocity required to support the seed surface on the large- and small-scale units.

Results, therefore, from a small draft-tube crystallizer can be more accurately extrapolated than from a small forced-circulation crystallizer.

Shown on Tables 2 and 3 are products from small and large machines of the draft-tube and forced-circulation types which illustrate this generalization.

Summary

A crystallizer of the circulating magma type is one wherein growing crystals are brought directly to the source of supersaturation. It has certain unique characteristics when properly applied which may be summarized as follows:

1. Reduction of supersaturation to low levels by recirculation of large volumes of body liquor minimizes the generation of nuclei, thus favoring the growth of larger crystals.
2. By maintaining extensive crystal seed surface in the zone of generation of supersaturation the tendency of salt to be precipitated on equipment surfaces can be minimized or eliminated.
3. There is only a negligible time interval between the instant when supersaturation is generated and when it is discharged upon growing crystals. Thus, there is minimum decay or dissipation of supersaturation in nuclei production. Also, this extremely short time interval between generation and deposition allows operation at higher supersaturation levels with any given rate of nucleation. It is common to find this design gives a high production per unit volume of a given product size.
4. Suspension of solids in the zone of supersaturation hydraulically as in the vacuum type results in a narrow product-size distribution.
5. When coupled with fine crystal (nuclei) removal devices, the product from this design can be varied from 200-10-mesh with many common salts.

Table 2. NaCl Produced in Forced-Circulation Evaporators

	2 FT.-0 IN.	10 FT.-0 IN. COMMERICAL EVAPORATOR			
		I EFFECT		II EFFECT	
	PILOT PLANT	TEST A	TEST B	TEST A	TEST B
Temp. Rise, °F.	5	4.8	7.2	4.2	6.3
Liq. Temp., °F.	(218)	220	220	198	198
Inlet Vel., ft./sec.	11.2	7.2	4.75	7.2	4.75
S ft. of fluid	2.3	2.36	4.0	1.46	2.16
ΔH, ft. of fluid	2.06	1.07	0.44	1.07	0.44
Np	0.53	0.67	0.63	0.67	0.63
N_{Fr}	1.92	0.16	0.07	0.16	0.07
$N_{Re} \times 10^{-6}$	2.5	7.9	5.25	7.9	5.25
D/S	1.20	4.25	2.5	6.85	4.65
Product, %					
+30 mesh		1.2	0.4	0	0.2
+40		10.6	28.4	1.6	11.6
+50		58.6	75.0	34.0	60.2
+60	20	76.8	87.5	61.9	78.6
+70		88.4	94.6	84.7	91.6
+100	90	96.2	99.0	96.4	98.6

$N_p = \Delta P g_c / V^2 \rho$

$N_{Fr} = V^2/Dg$

$N_{Re} = DV\rho/\mu$

ΔP = pressure drop, lb. force / sq. ft. (Body inlet to outlet)

V = inlet velocity, ft./sec.

ρ = density, lb.-mass/cu. ft.

g = gravity constant

D = body diameter, ft.

μ = viscosity, lb.-mass / (ft.) (sec.)

g_c = conversion factor

Table 3. KCl Produced in Draft-Tube Crystallizer

	2 FT.-0 IN. PILOT PLANT	12 FT.-0 IN. COMMERICAL
Prop. diam.	10 in.	48 in.
Prop. speed	160 rev./min.	125 rev./min.
Np	0.35-0.38	0.485
Nre	112,000	2,250,000
Product, %		
+14 mesh		0
+16	29.5	
+20	59.7	84.1
+30	73.3	96.5
+40	84.6	99.4
+60	93.1	
+70	96.3	

$N_p = Pg/\rho N^3 D^5$

$N_{Re} = D^2 N\rho/\mu$

P = Power, ft. lb./sec.

g = gravity constant

N = propeller speed, rev./sec.

D = propeller diameter, ft.

ρ = density, lb.-mass/cu. ft.

μ = viscosity, lb.-mass / (ft.) (sec.)

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Ethylene production process variables

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With the exception of the alkylates and aromatics contained in high-octane gasoline, ethylene is the major organic petrochemical, with an annual consumption of approximately 4 billion pounds. Most of the ethylene is produced in high-temperature pyrolysis operations utilizing ethane and propane as feedstocks *(32)*. Fundamental studies of ethylene production from low molecular weight hydrocarbons have generally been limited to conditions where the conversion of the feedstock is relatively incomplete. This coincides with industrial operating methods which are largely determined by the practical necessity of avoiding excessive coke formation. The yields of pyrolysis products are generally related to the percentage of hydrocarbon feedstock reacted, and each feedstock is considered separately since product distributions are influenced by the chemistry of the initial pyrolysis reactions *(4, 5, 10, 14, 30)*.

Ethane pyrolysis at severities giving partial conversions is primarily a simple dehydrogenation process in which only limited amounts of methane and higher molecular weight products are formed *(10)*. As the molecular weight of the feedstock increases, the rates of the initial pyrolysis reactions also increase, and secondary reactions become increasingly important in determining gaseous product distribution. Consequently, feedstocks ranging from propane to crude and residual petroleum oils yield gaseous products of similar composition which contain large proportions of propylene, butylene and butadiene. As pyrolysis severity increases, ethylene production first increases at the expense of the formation of the higher molecular weight olefins and diolefins, and then passes through a maximum as increased proportions of feed are converted to methane, coke, and hydrogen.

With premium feedstocks, such as natural gas liquids and paraffinic petroleum distillates, tube-furnace operation is feasible as long as pyrolysis severities are maintained at a level which does not give excessive coke formation. If it is desired to use high severities and/or low-grade petroleum oils, moving bed *(3, 13, 22, 23, 29)* or cyclic *(7, 9, 17, 27, 28)* cracking techniques must be employed. However, little interest has been shown so far in the use of fluidized solids, moving pebble beds and cyclic-regenerative furnaces for ethylene production, although in this type of equipment coke formation can be handled effectively and considerable freedom in the choice of pyrolysis conditions exists. Further, petrochemical and tar-processing operations based on pyrolysis of low-grade crude oils could be located near most of the major marketing areas because of the relatively low feedstock transportation and storage costs, and thereby achieve a considerable degree of independence from fluctuations in the raw material supply picture.

Basic process considerations

Most published pyrolysis studies concerned with the effects of operating variables on product distribution have as their objective tubular reactor design and are, therefore, generally limited to consideration of C_2-C_4 hydrocarbon feeds *(6, 25, 31, 34)*. In these design studies, an empirical or semiempirical kinetic model is set up which predicts the product distribution as a function of feed conversion, pressure, and temperature. Feed conversion, in turn, is related to space velocity or reaction time, pressure, and temperature. Design factors are obtained by a stepwise trial-and-error solution, or by iterative digital computer solution, of expressions defining extent of conversion, pressure drop, and enthalpy change in terms of common variables. Mass velocities, coil dimensions, and heat flux densities can then be selected for a given initial temperature and pressure. This relatively complex reactor coil design method is necessitated by the critical dependence of the coke deposition rate for any given feedstock on temperature patterns determined by heat flux density, tube dimensions, mass velocity, and on pressure.

Approach to Equilibrium. Ethane dehydrogenation is relatively slow compared to the primary pyrolysis reactions of the higher molecular weight paraffins *(32)* so that the extent of approach to C_2H_6—C_2H_4—H_2 equilibrium in the gaseous products is a good indication of pyrolysis severity *(10, 34)*. In the pyrolysis of natural gas liquids, petroleum, and shale oils, all of the two-carbon-atom species seem to be formed from a common unstable intermediate system *(15, 20)*. As a result, ethane, ethylene, and hydrogen are recovered in the pyrolysis products at the approximate equilibrium concentrations corresponding to the effective reaction temperature and pressure. This indicates that the reactions which maintain this subsystem in equilibrium must be considerably faster than the initial decomposition reactions, or the competing reactions leading to the formation of other pyrolysis products.

Pyrolysis severity ranges have been established for a number of paraffins and olefins, including methane, ethane, and ethylene, within which close approach to the C_2H_6-C_2H_4-H_2 equilibrium can be assumed *(15, 21)*. For natural gas liquids and petroleum oils, reaction temperatures above 1300° F. and reaction times above one second appear to be adequate *(15, 21)*. This includes the commercial range of pyrolysis severities in which the conversion of C_3-C_5 hydrocarbons can be far from complete, although C_2H_6-C_2H_4-H_2 equilibrium is attained. The existence of similar equilibrium relationships is also indicated for the C_3 and C_4 paraffin-olefin-hydrogen subsystems; however, large deviations from equilibrium occur at the lower pyrolysis severities due to the exces-

continued

continued

sive propane or butane concentrations when these materials are used as the feed. Thus, with the exception of systems in which unreacted feedstock interferes, the flowing equilibria:

$$C_iH_{2i} + H_2 \rightleftarrows C_iH_{2i+2}\ ;\ i = 2,3\ldots \quad \ldots \quad (1)$$

will closely approximate actual product distributions at severities employed in ethylene production.

Approach to chemical equilibrium by a subsystem of a complex reaction system is a useful characteristic since it allows the determination of the effective reaction temperature under conditions where actual measurement is difficult and not reproducible in different types and sizes of apparatus. Further, the knowledge that the forward- and reverse-reaction rates of any given subsystem are substantially greater than those of competing reactions is helpful in defining the course of the over-all reaction. For example, much evidence exists that the best molecular representation of methane formation by secondary pyrolysis reactions is relatively slow hydrogenolysis of low molecular weight paraffins, in flowing equilibrium with olefins of equal carbon number, and with hydrogen, in accordance with reaction system (1), *(15, 21)*:

$$C_iH_{2i+2} + H_2 \rightarrow CH_4 + C_{i-1}H_{2i};\quad i = 2, 3\ldots \quad (2)$$

In high-pressure hydrogenolysis of a variety of C_6-C_{12} hydrocarbons, where only trace quantities of olefins are present due to the effects of pressure and feed hydrogen on reaction system (1), one can observe the occurrence of optimum butane, propane, and ethane yields in sequence, accompanied by continually increasing methane yields. Further, at relatively high propane concentrations, methane and ethane are formed in equimolar quantities, as predicted by reaction (2), *(33)*.

Relative Rates of Major Secondary Reactions. Since any conversion of feed to methane constitutes, for all practical purposes, a permanent loss of an equivalent amount of carbon available for production of olefins and diolefins, excessive methane formation should be avoided by proper control of operating conditions. Short reaction times and low partial pressures have as favorable an influence on limiting methane formation as they have on limiting carbon formation. Methane recycle has been found to have some depressing effect on net methane yields, and a corresponding beneficial effect on olefin yields *(16)*. However, due to the apparent slowness of the reverse reactions of system (2), this effect is so small that its economic value is probably offset by the increased dilution of the product olefins.

The rate of secondary methane formation has been estimated from data obtained in the pyrolysis of 1/3 mole fraction ethylene—⅔ mole fraction hydrogen mixtures *(15)*. At atmospheric pressure, reaction temperatures of 1550 and 1700°F., and reaction times of 0.5 to 5 seconds, the apparent rate of ethane hydrogenolysis to methane was shown to be only a fraction of published values for the rate of ethane dehydrogenation, and the rate of ethane formation by ethylene hydrogenation *(34)*. Competing side reactions were also shown to be relatively slow. The resulting close approach to C_2H_6-C_2H_4-H_2 equilibrium *(21)*, and the nearly stationary ethane concentration at each temperature level, is the expected behavior of reaction systems (1) and (2) when $i = 2$.

Measurement of Pyrolysis Conditions. For the tube-furnace data on which a major portion of this study is based, maximum reaction temperatures were known with considerable certainty since it could be shown that sufficient heat was transferred, on assumption of laminar flow and absence of radiation effects, to permit close approach of the minimum reaction mass temperatures to tube wall temperatures at the highest throughput rates employed *(12, 15)*. This was confirmed by the close agreement of the experimental partial-pressure products for the ethane-ethylene-hydrogen subsystem and the equilibrium constants corresponding to the indicated maximum reaction temperature as discussed above.

It was further found that tube-furnace-yield data for natural gas liquids and petroleum and shale oils could be satisfactorily correlated with operating conditions employing reaction times computed from the exit-gas volume at average reaction conditions. This avoided the uncertainties introduced by attempts to approximate true reaction times of pyrolysis systems undergoing large volume changes. It can be seen below that the fictitious reaction time (θ) based on the exit-gas volume is proportional to the distance (L) from the entrance to the reaction zone of a flow reactor of given cross-sectional area (S), or to the corresponding volume (V_R); it is also related to the true reaction time (θ^*) based on the instantaneous reaction mass volume:

$$d\theta = \frac{SdL}{V_RF} = \frac{dV_R}{V_RF} \quad (3)$$

$$d\theta^* = \frac{SdL}{VF} = \frac{dV_R}{VF} \quad (4)$$

where V_R and V are the exit and instantaneous reaction mass volumes per unit mass respectively, and F is the mass rate. Thus, the reaction rates based on V and θ^*, V_R and θ, or the form used by Hougen and Watson *(11)* can be considered as equivalent:

$$r^*_i = \frac{-dn_i}{Vd\theta^*} = \frac{-dn_i}{V_Rd\theta} = \frac{-dn_iF}{dV_R} \quad (5)$$

where the value of r^*_i for a flow system of i components is defined as: moles of the ith component disappearing per unit volume of reaction mass per unit time.

In high-temperature pyrolysis flow systems, especially in the presence of a diluent gas, θ approximates the value of the true reaction time. It is, therefore, more useful as a correlation parameter than the reactant space velocity on a mass or volume basis, since the latter does not reflect the influence of pressure, temperature, and presence of inert diluents on reaction conditions. If desired, the value of θ^* for any given pyrolysis system and pyrolysis conditions can be approximated by graphical integration of Equation (4) on the basis of experimental data on the variation of V_R with F at constant V_R, or of V_R with V_R at constant F.

In the 42-in. heated length, 2⅛-in. diam. tubular reactor, consistent and reproducible results were obtained at a given partial pressure level over a a range of θ from 1 to 14 sec., achieved through the separate or combined effects of variation of feed rate, pressure, and dilution with inert feed gases, use of inserts to reduce free reactor volume, and heating of only two or three of the four furnace sections. The latter two methods were employed to limit the range of necessary variations in feed rate. When the inlet zone was not heated to reaction temperature, it was employed for preheat at indicated temperatures of approximately 800-1100°F. to reduce temperature gradients at the higher feed rates; the volume of the preheat zone was not considered in the computation of reaction time.

Prediction of gaseous product composition

In an earlier paper dealing with

this topic, two empirical functions of maximum reaction temperature (t) and the reaction time based on the total exit-gas volume θ were shown to be useful for defining pyrolysis behavior of natural gas liquids and petroleum and shale oils (*21*):

(a) The equilibrium approach function f_n/K_n, where f_n is the partial pressure product $P^{(c+d+\cdots)}(C)^c(D)^d \ldots / P^{(a+b+\cdots)}(A)^a(B)^b \ldots$ of a subsystem $aA + bB + \ldots \rightarrow cC + dD \ldots$, and K_n is the corresponding equilibrium constant.

(b) The pyrolysis severity function, $t\theta^{0.05}$.

It was found that approach to equilibrium could be predicted for the following subsystems:

(a) $C_2H_4 + H_2 \rightleftarrows C_2H_6$, $f_1 = K_{[1,2]}$

(b) $C_2H_6 + H_2 \rightarrow 2CH_4$, $f_2 = f_{[2,2]}(t,\theta)$

(c) $C_2H_6 + H_2 \rightarrow CH_4 + C_2H_4$, $f_3 = f_{[2,2]}(t,\theta)\ K_{[1,3]}/K_{[1,2]}$

where the bracketed subscripts refer to the system, and the highest carbon number of the system components respectively of reaction systems (1) and (2). The propylene-hydrogen-methane-ethylene system shown under (c) above, was used in preference to the propane-hydrogen-methane-ethane system defined by reaction system (2) for $i=3$, because of the small concentrations of propane in the high-temperature pyrolysis products of feeds other than propane, and the interference of undecomposed propane when used as a feedstock. System (c) was also considered of importance by Myers and Watson in their selection of effective over-all secondary reactions in propane pyrolysis (*25*).

At the reaction times and temperatures employed in the tube-furnace study (1-14 sec., 1300-1600°F.), acetylene concentrations in the pyrolysis products of propane and higher molecular weight feedstocks were significantly below the anticipated equilibrium value, although in the pyrolysis of C_2H_4-H_2 and C_2H_6-H_2 mixtures in the same range of conditions, the subsystem:

(d) $C_2H_2 + H_2 \rightleftarrows C_2H_4$

did maintain close approach to equilibrium ($f_4 = K_4$) (*21*). It is likely that, at long residence times, acetylene yields characteristic of the indicated pyrolysis conditions are affected by quench-zone conditions in the presence of large concentrations of highly reactive precursors of nongaseous products.

Butadiene concentrations also approached equilibrium values defined

continued

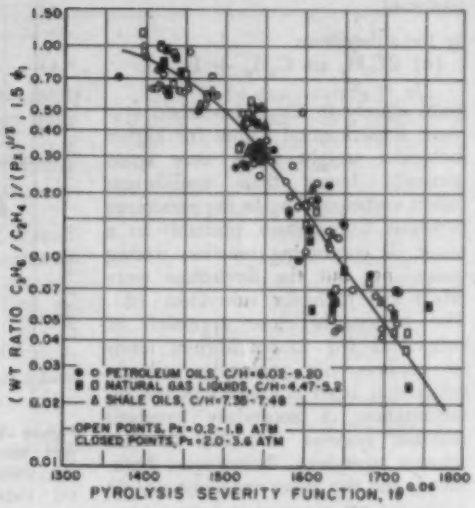
(WT RATIO C_3H_6/C_2H_4)/$(P_2)^{1/3}$, ϕ_1
PYROLYSIS SEVERITY FUNCTION, $t\theta^{0.05}$
● ○ PETROLEUM OILS, C/H=6.02-9.20
■ □ NATURAL GAS LIQUIDS, C/H=4.47-5.2
▲ SHALE OILS, C/H=7.35-7.48
OPEN POINTS, P_2=0.2-1.8 ATM
CLOSED POINTS, P_2=2.0-3.6 ATM

Figure 1. Effect of pyrolysis severity on propylene/ethylene weight ratio (normalized to 1 atm. partial pressure)

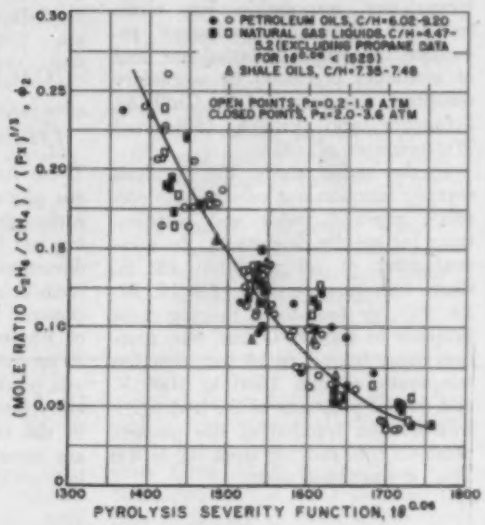
(MOLE RATIO C_2H_6/CH_4) / $(P_2)^{1/3}$, ϕ_2
PYROLYSIS SEVERITY FUNCTION, $t\theta^{0.05}$
● ○ PETROLEUM OILS, C/H=6.02-9.20
■ □ NATURAL GAS LIQUIDS, C/H=4.47-5.2 (EXCLUDING PROPANE DATA FOR $t\theta^{0.05} < 1525$)
▲ SHALE OILS, C/H=7.35-7.48
OPEN POINTS, P_2=0.2-1.8 ATM
CLOSED POINTS, P_2=2.0-3.6 ATM

Figure 2. Effect of pyrolysis severity on ethane/methane mole ratio (normalized to 1 atm. partial pressure)

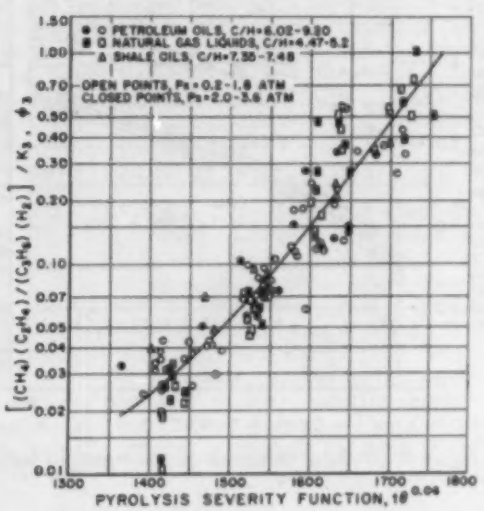
$[(CH_4)(C_2H_4)/(C_2H_2)(H_2)]/K_3$, ϕ_3
PYROLYSIS SEVERITY FUNCTION, $t\theta^{0.05}$
● ○ PETROLEUM OILS, C/H=6.02-9.20
■ □ NATURAL GAS LIQUIDS, C/H=4.47-5.2
▲ SHALE OILS, C/H=7.35-7.48
OPEN POINTS, P_2=0.2-1.8 ATM
CLOSED POINTS, P_2=2.0-3.6 ATM

Figure 3. Effect of pyrolysis severity on approach of propylene-hydrogen-methane-ethylene system to equilibrium.

continued

by the subsystem:

(e) $2C_2H_4 \rightleftarrows C_4H_6 + H_2$,

$f_5 = K_5$

quite closely in C_2 hydrocarbon systems. Experimental values for higher molecular weight feeds were again generally lower than equilibrium values corresponding to the maximum pyrolysis temperature, probably as a result of continuing reaction during quenching, but the deviations were much less than for subsystem (d). The reasonably close approach of subsystem (e) to equilibrium tends to confirm the molecular scheme which has been employed in the interpretation of secondary pyrolysis reaction systems *(15, 20)*. In this scheme, acetylene, diacetylene, butadiene, and the lower molecular weight aromatics are assumed to have a common primary reaction intermediate which is in equilibrium with the intermediates responsible for olefin formation. Similar conclusions regarding the origin of butadiene, and of aromatics produced by secondary reactions, were reached by Groll *(8)*, Schneider and Frolich *(30)*, and Weizmann *et al. (35)*.

In the earlier study, the pyrolysis severity function was used only to correlate product yields and distributions for specific feedstocks. In a reevaluation of all available 2¼ in. diam. tube-furnace data *(18, 19, 21, 24, 26)* for feedstocks ranging from propane to Bunker C fuel oils, reaction times from 1 to 14 sec., reaction temperatures from 1300 to 1600°F. and partial pressures of the hydrogen-hydrocarbon fraction of the gaseous products *(Px)* ranging from 0.2 to 3.6 atm., it was found that:

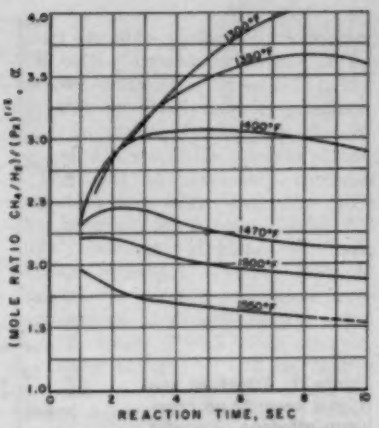

Figure 4. Relationship between pyrolysis temperature, reaction time, and calculated methane/hydrogen mole ratio (normalized to 1 atm. partial pressure)

$$(C_2H_6)/(Px)^{1/3}(CH_4) = \phi_1\ (t\theta^{0.68}) \quad (6)$$

$$(C_2H_6)/(Px)^{1/3}(CH_4) = \phi_2\ (t\theta^{0.68}) \quad (7)$$

$$f_3/K_3 = \phi_3\ (t\theta^{0.68}) \quad (8)$$

These functions of pyrolysis severity are plotted in Figures 1, 2, and 3. Although there is considerable scattering, no tendency towards systematic deviations for the various types of feedstocks and the different partial-pressure ranges is apparent. The plot of Figure 1 relates the weight ratio of propylene to ethylene in the pyrolysis products to the operating parameters instead of the mole ratios used in the other plots, since these units are more useful in estimating propylene yields from a correlation of ethylene yield, feedstock C/H weight ratio and operating conditions which will be presented in the following section.

The curves of Figures 1 and 3 were drawn to give the best agreement between experimental methane-hydrogen mole ratios and values calculated from the plots of Figures 1 and 3 by means of the expression:

$$(CH_4)/(Px)^{1/3}(H_2) = \phi_1\ \phi_2\ K_3 \quad (9)$$

The calculated values are plotted in Figure 4.

From the correlations of Figures 1, 2, and 3 under assumption of close approach to the equilibria of reaction system (1), it is possible to make rough estimates of gaseous product compositions. For this purpose, the relationship between the pyrolysis severity function for the 2¼ in. diam. tube furnace data used in this study, and equivalent parameters characterizing the operating conditions in other types of apparatus, must be known.

Effective pyrolysis temperatures can be related to measured temperatures on the assumption of ethane-ethylene-hydrogen equilibrium. At constant partial pressure, the free hydrogen concentration in the gaseous products *(21)* or the propylene-ethylene and ethane-methane ratios (Figures 1 and 2), show a direct dependence on pyrolysis severity, with the free hydrogen content probably being the most convenient empirical parameter of severity.

The heating value (gross heat of combustion per unit volume at standard conditions) of the hydrogen-hydrocarbon fraction of the product gas is also a good parameter of pyrolysis severity, and approaches an inverse linear relationship with the

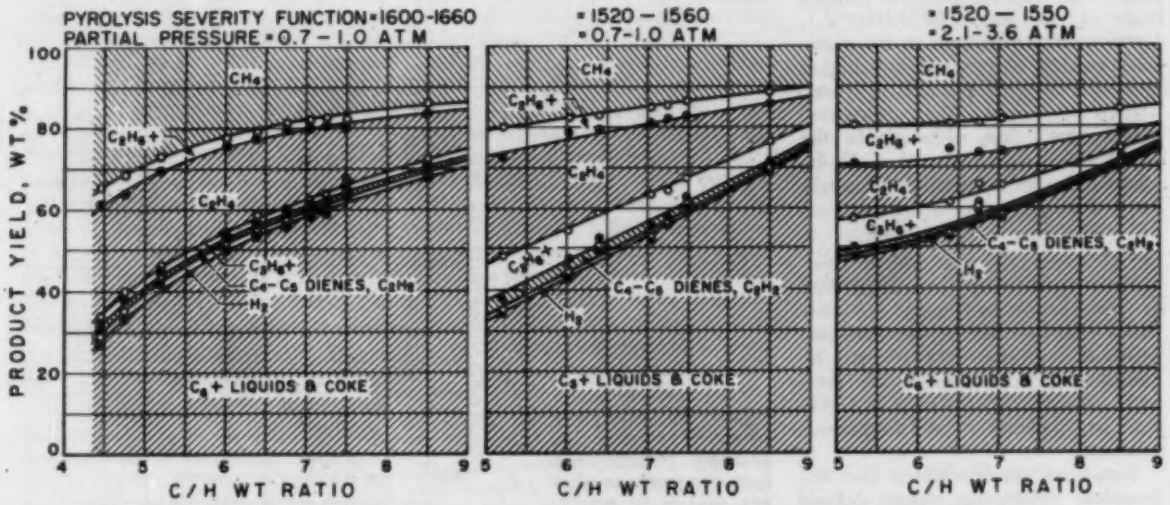

Figure 5. Effects of feedstock carbon/hydrogen weight ratio and operating conditions on pyrolysis yields

NOTATION

$a, b \ldots n$ = stoichiometric coefficients of reacting species, A, B ...N

$(A),(B)\ldots(N)$ = mole fractions of components in total exit gas (when used in conjunction with absolute pressure P) or in H_2-gaseous hydrocarbon fraction of total exit gas (when used in conjunction with partial pressure Px)

C/H = carbon - hydrogen weight ratio of feedstock

F = feed rate, unit mass per second†

f_n = partial pressure product, $P^{(c+d+\ldots)}(C)^c(D)^d \ldots / P^{(a+b+\ldots)}(A)^a(B)^b \cdots$, of nth subsystem, $aA + bB + \ldots \rightarrow cC + dD + \ldots$, in reaction mass

$f_{[1,i]}, f_{[2,i]}$ = partial pressure products of olefin hydrogenation (1) and paraffin hydrogenolysis (2) systems of maximum carbon number $i = 2,3\ldots$

K_n = f_n at equilibrium

$K_{[1,i]}, K_{[2,i]}$ = $f_{[1,i]}$ and $f_{[2,i]}$ at equilibrium

L = distance from reaction zone entrance of flow reactor†

L_R = length of flow reactor†

n_i = moles of ith component in reaction mass per unit mass of feed†

P = absolute reaction pressure, atm.

R = gas constant, 0.08205 (liter) (atm.)/(g.-mole) (°K.)

r^*_i = reaction rate, moles of ith component disappearing per second per unit volume†

S = cross-sectional area of flow reactor†

T = reaction temperature, °K.

t = maximum temperature in flow reactor, °F.

V = instantaneous volume of reaction mass (at reaction conditions) per unit mass of feed†

V_R = total exit gas volume at average reaction conditions per unit mass of feed†

V_R = reactor volume†

x = mole fraction of hydrogen plus gaseous hydrocarbons in total exit gas

Greek Symbols

α = empirical function defining $(CH_4)/(Px)^{1/3}(H_2)$ in terms of t and θ

ϕ = empirical function of $t\theta^{0.05}$ defining relationship between mole ratio of selected gaseous pyrolysis products, Px and pyrolysis severity

θ = reaction time based on P, free volume of reaction zone, and total exit gas flow rate (hydrogen, gaseous hydrocarbons, inert gases and steam), neglecting volume contribution of nongaseous products, as calculated from ideal gas law, seconds

θ^* = true reaction time, seconds.

† In consistent units

function $t\theta^{0.05}$ over much of the range of tube furnace data employed in this study (*19, 21*). Since the specific gravity and heating value of hydrogen-gaseous hydrocarbon mixtures exhibit a linear interdependence, these two parameters of pyrolysis severity are useful for control purposes, especially when no diluent other than steam is used, and when preliminary cooling and liquid product separation steps reduce C_6-plus hydrocarbon content to a low and constant level.

To obtain an estimate of gaseous product composition as a function of the reaction temperature and time, and the partial pressure of the hydrogen-gaseous hydrocarbon fraction of the product gas, it is necessary to solve n-1 simultaneous equations relating the molar hydrogen-gaseous hydrocarbon distribution of n components to empirical functions of the operating parameters and the applicable equilibrium constants for the condition that the summation of the mole fractions of the components equals one. Below, such a system is set up for the case where only H_2, CH_4, C_2H_6, C_2H_4, C_3H_8 and C_4H_6 are assumed to be present in significant concentrations:

Values for maximum reaction temperature (t in °F.), absolute reaction pressure (P in atmospheres), mole fraction of hydrogen plus gaseous hydrocarbons in total exit gas (x), and reaction time based on total exit gas volume at average reaction zone temperature and pressure (θ in sec.), are known. The values of ϕ_1, ϕ_2 and ϕ_3 are defined by Figures 1, 2, and 3; the values of the equilibrium constants are determined by t; the value of $\alpha = \phi_1 \phi_3 K_3$ is plotted in Figure 4.

(H_2) = assumed value

$(CH_4) = \alpha(H_2)(Px)^{1/3}$

$(C_2H_6) = \alpha(H_2)\phi_3(Px)^{2/3}$

$(C_2H_4) = \alpha\phi_2/K_1(Px)^{1/3}$

$(C_3H_8) = \alpha\phi_1\phi_2/K_1$

$(C_4H_6) = \alpha^2\phi_3^2K_3/(H_2)K_1^2(Px)^{2/3}$

Values of (H_2) are assumed until the summation of the mole fractions of gaseous product constituents equals one, or a value of one less the estimated mole fraction of gaseous hydrocarbon constituents of the pyrolysis products not considered in the expressions listed above (correlations were developed on the basis that any C_6-plus hydrocarbons present the product gas after liquid products recovery are included in x).

This method is applicable when the primary pyrolysis reactions are essentially completed and is, therefore, of primary interest in cases where pyrolysis apparatus capable of handling substantial carbon deposition can be employed.

Prediction of product yields

Figure 5 illustrates the direct dependence of product distribution on C/H weight ratio in the 4.5-9 range at pyrolysis severities which insure that complete decomposition of the feedstock has been approached. This eliminates data for propane below $t\theta^{0.05} = 1600$ and data for butane below $t\theta^{0.05} = 1500$-1550. The distribution between gaseous and nongaseous products is primarily the result of the

continued

continued

expected effect of feedstock C/H weight ratio on the relative abundance of a high hydrogen content H_2—C_2-C_3 hydrocarbon fraction and a low hydrogen content aromatic C_6-plus hydrocarbon and coke fraction. The close agreement of actual results with these simple stoichiometric considerations reflects the limited influence of feedstock properties on gaseous product composition in the high severity range. The method of computation employed for Figure 5 does not make any allowance for the sulfur, oxygen, nitrogen and ash content of the feedstock, so that all pyrolysis products other than the H_2—C_1-C_3 hydrocarbon fraction are shown as nongaseous products. Due to the relatively high content of these minor constituents in crude shale oil, the results shown for this feed (approximately 7.5 C/H weight ratio) deviate significantly.

Figure 5 clearly shows the rapid decrease of ethylene and propylene yields with increases in feedstock C/H weight ratio and the corresponding increase in nongaseous products. Increase in product gas partial pressure over a relatively limited range also causes a sharp decrease in olefin formation. Much of this decrease appears as an increase in gaseous paraffin yield, especially at high feedstock C/H weight ratios where a lesser effect of partial pressure on total gaseous product yield appears to exist.

As noted before, nongaseous product distribution cannot be readily predicted since, particularly for the higher molecular weight, high C/H weight ratio materials, a significant portion of the nongaseous products is not the result of vapor-phase pyrolysis reactions. Further, the relative formation of liquid products and coke is controlled by feedstock properties other than C/H weight ratio as well as operating conditions. In general, increase in feedstock molecular weight, or molecular weight range, results in a shift from lower molecular weight aromatics to higher molecular weight aromatics content of the liquid products, and higher coke yields (*19, 21, 35*). The minimum coke yield corresponds to the Conradson carbon residue value of the feedstock; actual coke yields can be significantly higher at pyrolysis severities above $t\theta^{0.06}$= 1550. At high severities, vapor-phase carbon (lamp black) is also formed.

To permit direct estimates of ethylene yields as a function of feedstock C/H weight ratio (4.5-9), pyrolysis severity ($t\theta^{0.06}$=1400-1750) and partial pressure (Px=0.2-3.6 atm.) an empirical correlation was developed on the basis of the 2½ in. diam. tube furnace data:

$$\text{wt. \% } C_2H_4 = \left[(220/C/H) - 16\right] \left[e^{-\left(\frac{t\theta^{0.06} - 1570}{45\ C/H}\right)^2}\right] \left[1 - 0.75 \log (Px)\right] \quad (10)$$

The agreement between actual and estimated ethylene yields, and the effects of process variables on ethylene yield, are shown in Figure 6. Experimental points obtained at low severities for propane and butane are omitted because of severe scattering. Natural gasoline also shows considerable scattering at low severities. However, even in this range which includes conditions employed in current commercial tube-furnace operations, the correlation predicts yield trends quite well. There is a tendency for the results in the high partial pressure range to show larger deviations, and for estimated values for high C/H weight ratio feedstocks to be too high.

For the range of reaction times used, all feedstocks tend to give maximum ethylene yields in the 1550-1600 pyrolysis severity range. However, as shown by Schutt and Zdonik (*32*), this may not correspond to optimum operating conditions even if carbon deposition is not a limiting factor. In this range of severities, propylene yields are only 25 wt. % of ethylene yields (Figure 1). For propane, at one atmosphere partial pressure and $t\theta^{0.06}$=1570, this would correspond to a total C_2-C_3 olefin yield of 42 wt. %, whereas, at severities of 1500-1525, total C_2-C_3 olefin yields are 44 wt. % on the basis of Equation (10) and Figure 1. Predicted values are in reasonably good agreement with published single-pass data for pyrolysis of low C/H ratio feedstocks under commercial tube-furnace-operating conditions (at severities defined by the observed propylene-ethylene ratios and Figure 1) (*8, 14, 30, 32*). Agreement with Thermofor pyrolytic cracking (TPC) data obtained with propane and a number of petroleum crudes and fractions in a 1 bbl./day pilot unit is also satisfactory, if uncertainties due to insufficient published information for complete characterization of the operating variables are taken into consideration (*3*).

Table 1. Comparison of pyrolysis product distribution

Apparatus	TUBE FURNACE[21,32]			
Run No.	328		339	
Feed Stock				
°API	21.4			
C/H Ratio	7.04			
Conradson Carbon Residue, wt %	4.4			
Total Pressure, atm	1.02		1.00	
Partial Pressure, atm (a)	0.751		0.687	
Reaction Temperature, °F(b)	1470		1550	
Reaction Time, sec	2.51		2.40	
Pyrolysis Severity, $t\theta^{0.06}$	1554		1634	
Gaseous Products	Mole %	Wt %	Mole %	Wt %
CH_4	40.8	15.11	43.2	18.19
C_2H_6	5.2	3.62	2.5	1.94
C_3H_8	0.2	0.21	0.1	0.12
Butanes	0.1	0.14	—	—
C_2H_4	27.5	17.89	23.4	17.23
C_3H_6	6.0	5.86	1.5	1.09
Butenes	0.8	1.06	0.1	0.15
Pentenes	—	—	—	—
Butadiene	1.9	2.43	0.6	0.87
Cyclopentadiene	0.4	0.62	0.1	0.18
Acetylene	0.3	0.18	0.4	0.28
Hydrogen	16.8	0.78	28.1	1.49
Total	100.0	47.90	100.0	42.14
Liquid Products, wt % (c)				
0-200°C Distillate	12.53		9.00	
200-300°C	8.05		8.83	
300-355°C	4.73		3.58	
Pitch(d)	19.40		25.22	
Total	44.71		46.63	
C/H Ratio of Liquid Products(e)	16.53		19.78	
Coke, wt %(f)	7.39		11.23	

Footnotes ⇨ (a) Hydrogen plus gaseous hydrocarbons (including C_6-plus aromatics recovered in vapor-phase).

Pyrolysis of low-grade oils

In Table 1, pyrolysis yields obtained in different types of apparatus from reduced crudes of similar properties at moderate and high severities are compared. Included are data from (a) the 2½-in. diam. tube furnace (*21, 26*), (b) a cyclic-regenerative pilot unit of 50 gal./hr. nominal capacity (*28*), (c) a 1-2 bbl./hr. capacity TPC pilot unit employing ¼ to ¾-in. diam. coke pebbles as heat transfer medium (*1*, 22, 23), and (d) a 2-3 gal./hr. capacity fluid-bed pilot unit employing 40-mesh silica gel as heat transfer medium (29). Design features and operating characteristics of these units have been described in detail. However, it should be noted that cyclic-regenerative pyrolysis of petroleum oils requires apparatus patterned after that used in utility gas manufacture (*9, 27*), which differs from the design developed for operation with lower molecular weight hydrocarbons (7) by making provisions for direct water quench of hot pyrolysis products to remove tar and pitch.

It can be seen from Table 1 that pyrolysis yields at the two pyrolysis severity levels are roughly comparable in spite of considerable variations in processing conditions. Although the pyrolysis severity function $t\theta^{0.04}$ is given where the necessary data are available, the gaseous-products yield shows the most consistent trend when compared on the basis of the propylene-ethylene ratio.

The nongaseous products obtained at equivalent severities are also similar except that with the Surface Combustion Corporation TPC unit (*1*, 22, 23) design, pitch yields are lower, and coke formations correspondingly higher. This is the result of a pebble quench which removes the highest molecular weight pyrolysis products leaving the reaction zone through contact with a side-stream of 750-800°F. coke pebbles to avoid offtake plugging. Coke formations in the cyclic pilot unit tests were below the Conradson carbon residue value of the feedstock, possibly as a result of equipment design characteristics (28). In commercial cyclic operation at severities suitable for ethylene production, coke laydown during the process oil introduction portion of the cycle, as calculated from stoichiometric balances over the blast (reheat) portion of the cycle, is usually higher (wt. %) than the Conradson carbon residue value of feedstock (*17, 19*).

The high C/H weight ratio of the liquid products, even at the lower severities, shows them to be predominantly aromatic. The 0-200°C. distillate and the pitch (residue above 355°C.) are potentially premium products. The distillate fraction consists of benzene, toluene, xylenes, styrene and various C_9-plus aromatics (3), and the pitch is suitable as a binder for the carbon electrodes used in aluminum production (2). Significant quantities of naphthalene are also produced. The coke recovered in TPC operation is of electrode grade if produced from low-ash content feedstock (*1*).

An indication of the economics of production of petrochemical crudes

continued

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obtained with reduced crude oil in various types of apparatus

	CYCLIC[28]				FLUID BED[23]		TPC[22]			
	16		17		31-B		4		1	
Temperature, °F.		23.0			21.4			18.5		
Pressure, p.s.i.g.		6.99			7.04			7.36		
Residence time, sec.		5.3			4.4			7.9		
Steam/oil, wt.	1.38		1.46		1.71		—		—	
Pebble/oil, wt.	0.42		0.46		0.39		—		—	
Pyrolysis severity, $t\theta^{0.04}$	1530		1608		1348		1400		1650	
Propylene/ethylene, wt.	3.24		3.03		8.5		—		—	
Pyrolysis severity, $t\theta^{0.04}$	1642		1719		1536		—		—	
	Mole %	Wt %	Mole %	Wt %	Mole %	Wt %	Mole %	Wt %	Mole %	Wt %
Hydrogen	42.4	17.46	42.9	19.18	32.0	11.46	34.7	11.09	37.3	16.04
Methane	3.2	2.48	1.7	1.43	5.9	3.93	6.2	3.73	2.4	1.96
Ethane	0.1	0.13	—	—	0.6	0.59	1.2	1.06	0.3	0.36
Propane	—	—	—	—	0.3	0.39	0.1	0.12	—	—
Ethylene	25.6	18.45	20.7	16.15	23.6	14.73	23.3	13.01	23.5	17.63
Propylene	3.9	4.21	0.8	0.93	7.6	7.11	9.8	8.24	2.0	2.28
Butadiene	0.2	0.33	0.3	0.53	1.2	1.51	1.8	2.02	0.2	0.30
Butenes	—	—	—	—	—	—	0.2	0.28	—	—
Acetylene	0.9	1.27	0.6	0.86	1.5	1.82	2.1	2.27	0.7	1.03
Carbon monoxide	0.2	0.39	0.2	0.42	0.6	0.89	0.6	0.79	0.2	0.36
Carbon dioxide	0.3	0.23	0.8	0.56	—	—	0.3	0.16	0.6	0.42
Benzene	23.2	1.20	32.0	1.80	26.7	1.20	19.7	0.79	32.8	1.76
Total	100.0	46.15	100.0	41.86	100.0	43.63	100.0	43.56	100.0	42.14
Toluene	11.48		9.44				11.71		9.76	
Xylenes	8.09		12.96				7.31		7.36	
Styrene	5.69		5.73				6.32		4.39	
C_9-plus aromatics	24.67		26.07				17.60		17.15	
Total aromatics	49.93		54.20		50.31		42.94		38.66	
Pitch	18.31		20.04		14.74		14.09		26.64	
Coke	3.92		3.94		6.06		13.5		19.2	

(b) Maximum value for tube furnace, average value for cyclic and fluid-bed and nominal value for TPC operation.

(c) Corrected to 100% material balance; also includes sulfur, oxygen, nitrogen and ash content of feedstock.

(d) By difference.

(e) From carbon hydrogen balance.

(f) Assumed to contain 6 wt % H_2.

continued

from lower grade petroleum oils can be obtained from consideration of raw material, utility and investment costs in cyclic and Thermofor pyrolytic cracking. From a typical reduced crude or low-grade crude with the properties: 7.2 C/H wt. ratio, 21 °API (7.7 lb./gal.) and 6 wt. % Conradson carbon residue, the olefin and diolefin yields which can be expected at moderate severities in these types of operation on the basis of the data of Table 1 and Figure 5 are shown as follows in Table A:

Table A

	Yield wt. %
C_2H_4	17.0
C_2H_4 from 4.0 wt. % C_2-C_4 paraffin recycle (estimated)	2.5
C_3H_6	5.5
C_4H_8	1.5
C_4H_6	2.0
C_5H_8	0.5
Total	29.0

At moderate severity, the total gas yield (H_2, C_1-C_5 hydrocarbons) from the typical reduced crude feed described above will be about 45 wt. %, and carbon deposition will be about 9 wt. % in cyclic operation, and 14 wt. % in TPC operation. Thus, on the assumption of 100% product recoveries, liquid products, ranging from benzene to pitch will be about 46 wt. % for cyclic operation and 41 wt. % for TPC operation. As noted above, the lower value for the latter is due to the removal of pitch in the pebble quench.

In cyclic operation, process heat requirements for converting the feed to pyrolysis products at operating temperature are about 1800 B.t.u./lb. and the over-all efficiency of process heat utilization can be assumed to be 60%. Combustion of deposited coke (16,000 B.t.u./lb.) is used to supply a portion of heat requirements (*17*).

In TPC operation, pilot plant data extrapolated to 6000 bbl./day capacity indicate a total fuel requirement of 3500-4000 B.t.u./lb. of feedstock (flue gas leaving at 1100°F.) (*1*). The same data also indicate that 8 lb. coke per million B.t.u. fuel input will be gasified in the pebble heater, reducing the recoverable yield proportionally (*1*).

The tail gas from C_2-C_5 hydrocarbon removal can be used as supplementary fuel and will be in considerable excess of requirements in case of cyclic operation. The estimated raw material and utility costs for the pyrolysis are 1.5-2.0¢/lb. C_2-C_5 olefins and diolefins, assuming 7.5¢/gal. process oil, 70¢/1000 lb. steam, 10¢/gal. liquid byproducts credit, 30¢/million B.t.u. excess tail gas credit in cyclic operation and $10/ton credit for TPC coke.

A reduced crude oil pyrolysis plant of about 6000 bbl./day capacity, could produce 400,000 lb./day of ethylene, including the estimated yield from C_2-C_4 paraffin recycle. Total C_2-C_5 olefin and diolefin capacity would approach 600,000 lb./day and liquid by-products yield would be about 100,000 gal./day. About 4.5 billion B.t.u./day of excess tail gas would also be available in cyclic operation and a coke yield of about 100 tons/day would be obtained in TPC operation. The cost of a cyclic-regenerative plant with this capacity, excluding site, site improvements, steam plant, general plant buildings, oil and finished by-product storage, and any gas processing other than that necessary for a crude separation of liquid products, has been estimated at 5.5 million dollars (*17*). The cost of a TPC unit and auxiliaries of equivalent capacity has been estimated at about 3 million dollars (*1*, *22*).

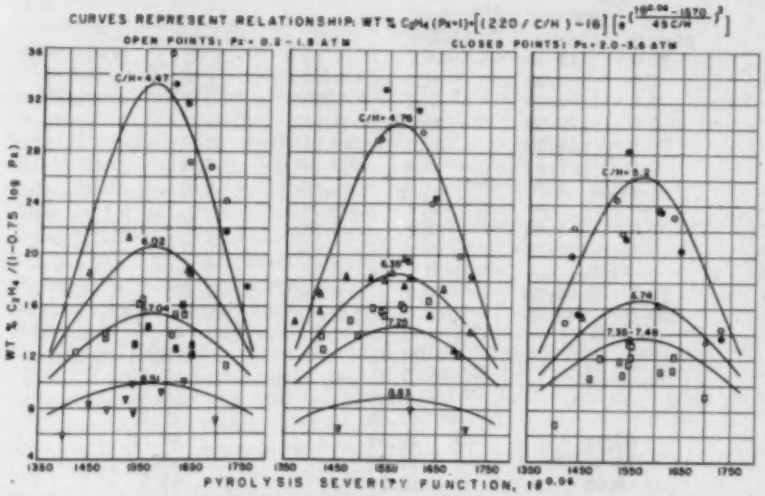

Figure 6. Effects of feedstock carbon/hydrogen weight ratio and pyrolysis severity on ethylene yield (normalized to 1 atm. partial pressure)

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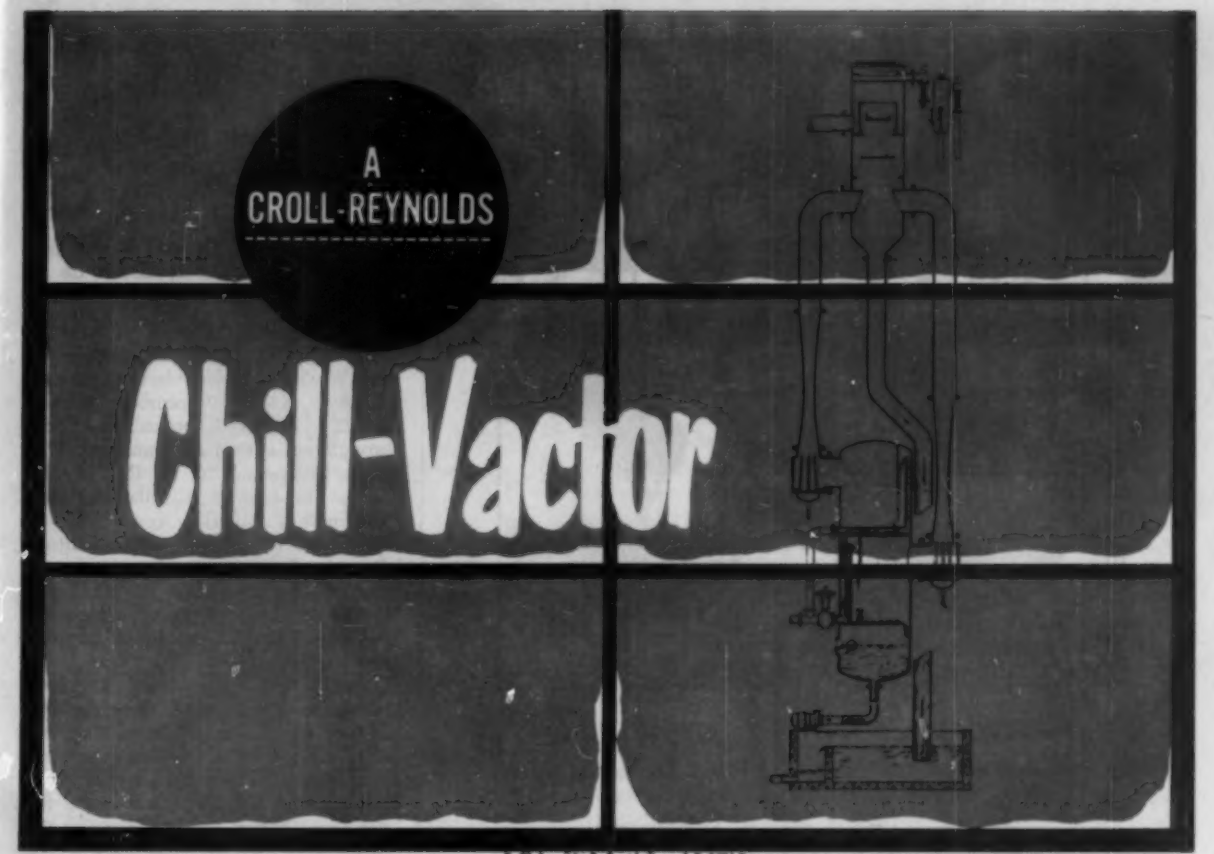

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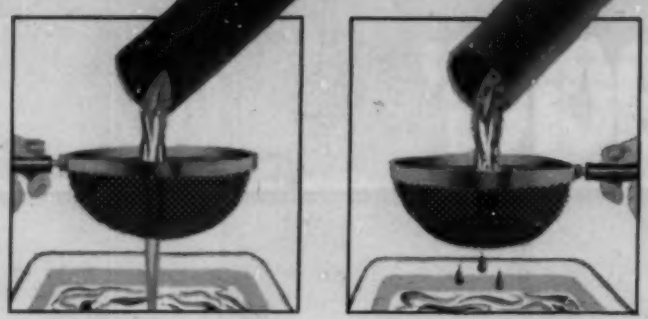

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Major naphthalene distillation unit on line

Allied Chemical plant at Philadelphia (Frankford), Pa., said to be world's largest.

Despite domestic threats of naphtalene overproduction plus an unfavorable market position vis-a-vis foreign imports (*CEP*, November, Scope, p. 21), Allied Chemical has just brought on stream at Frankford, Pa., what is claimed to be the world's largest naphtalene distillation unit. The new installation (capacity unspecified) replaces a steam-heated, direct-fired, 3-column atmospheric and vacuum distillation system, which required a battery of six centrifuges to produce 78° melting point naphtalene.

In the new Badger-built Frankford plant, overhead take-off from the first of four columns is crude solvent destined for use in production of styrene for resins and industrial solvents; from the second column comes crude hi-flash from which "CUMAR" resins are made; and from the third column, an intermediate fraction which is reprocessed. After processing in the first three columns, the naphthalene product is distilled off in the fourth column. All columns are equipped with perforated-type trays operating at reduced pressures. The high-temperature-level heat required for the naphalene column is supplied by a vertical, direct-fired tube still.

The entire plant can be operated by one man by means of a semigraphic control panel equipped with miniature instruments. A pneumatic process control system is used throughout.

Oxygen capacity at U.S. Steel's Gary Works will be doubled by installation of a second unit rated at 94 million cubic feet per month. This second unit, like the first, which went on stream in June, 1958, will be built, owned, and operated by Linde Co. (Union Carbide) on property leased from U.S. Steel. The new plant will also turn out 256 million cubic feet per month of high-purity dry nitrogen, to be used chiefly for blanketing during annealing operations.

The name of Sinclair Chemicals, Inc., wholly-owned subsidiary of Sinclair Oil, has been changed to Sinclair Petrochemicals, Inc.

solution chemistry in fused salts

A novel approach to the study of fused salts, developed at Argonne, is providing new insights into their solution chemistry and structure.

Studies of the absorption spectra of these unique solvents containing actinide, lanthanide, and other transition metal ions are yielding detailed information concerning oxidation states, oxidation-reduction reactions, complex ion formation, coordination numbers, and reaction rates.

This new knowledge is made possible because of the development of convenient techniques for measuring fused salt spectra at temperatures up to 1500°K. The interpretation of these measurements is greatly facilitated by the key finding that the transition metal ion spectra in fused salts are similar to their spectra in aqueous solutions and in crystals.

Fused salts are already important in many areas of nuclear technology, including high temperature homogeneous reactors, fuel processing systems, and the refining of metals such as thorium, uranium, and plutonium.

Still other areas of application, among them the thermonuclear energy field, are being explored as a result of the continuing fundamental investigations of these versatile materials.

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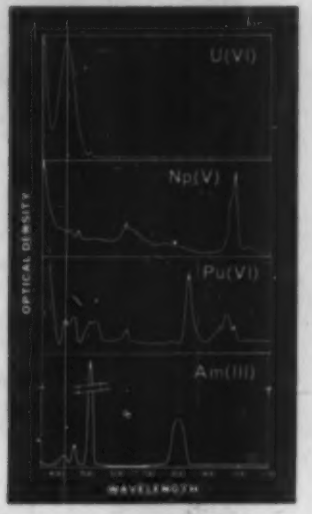

The stable oxidation states of the actinide ions in molten $LiNO_3$-KNO_3 eutectic, as revealed through their absorption spectra, are U(VI), Np(V), Pu(VI), and Am(III).

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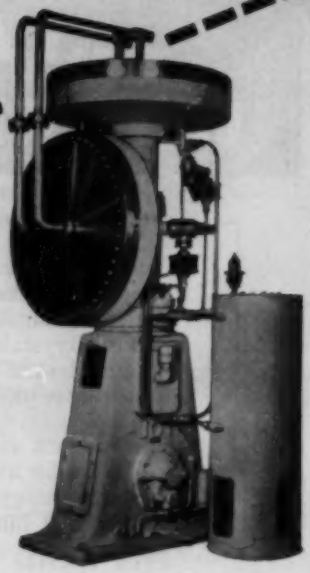

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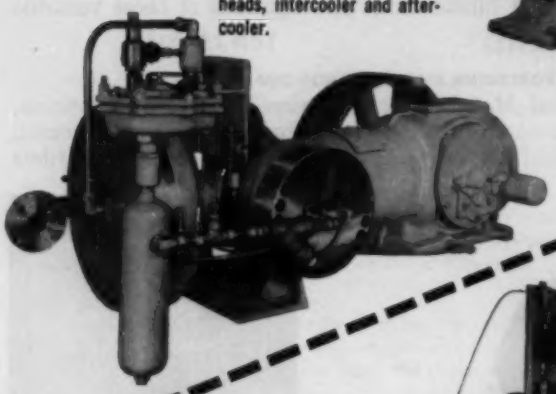

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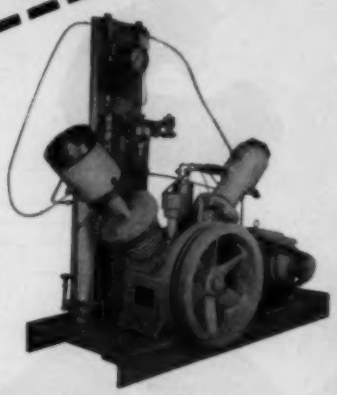

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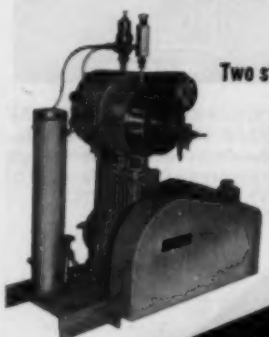

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industrial news

All assets of the second largest firm in the fiber glass industry, L.O.F. Glass Fibers Co., have been acquired by the newly-organized Johns-Manville Fiber Glass Inc., wholly-owned subsidiary of Johns-Manville Corp. Expansion plans are said to be in the works.

The St. Gobain phosphate fertilizer process is being used in the just-completed $2 million phosphate fertilizer plant of Coastal Chemical at Pascagoula, Miss. The plant, first in the U.S. to employ the French-developed process, includes a 75 ton/day phosphoric acid unit and a 350 ton/ day granulated ammonium phosphate fertilizer unit. Feature of the process for manufacture of phosphoric acid is said to be a single-stage rock digestion system. Construction was by Fluor.

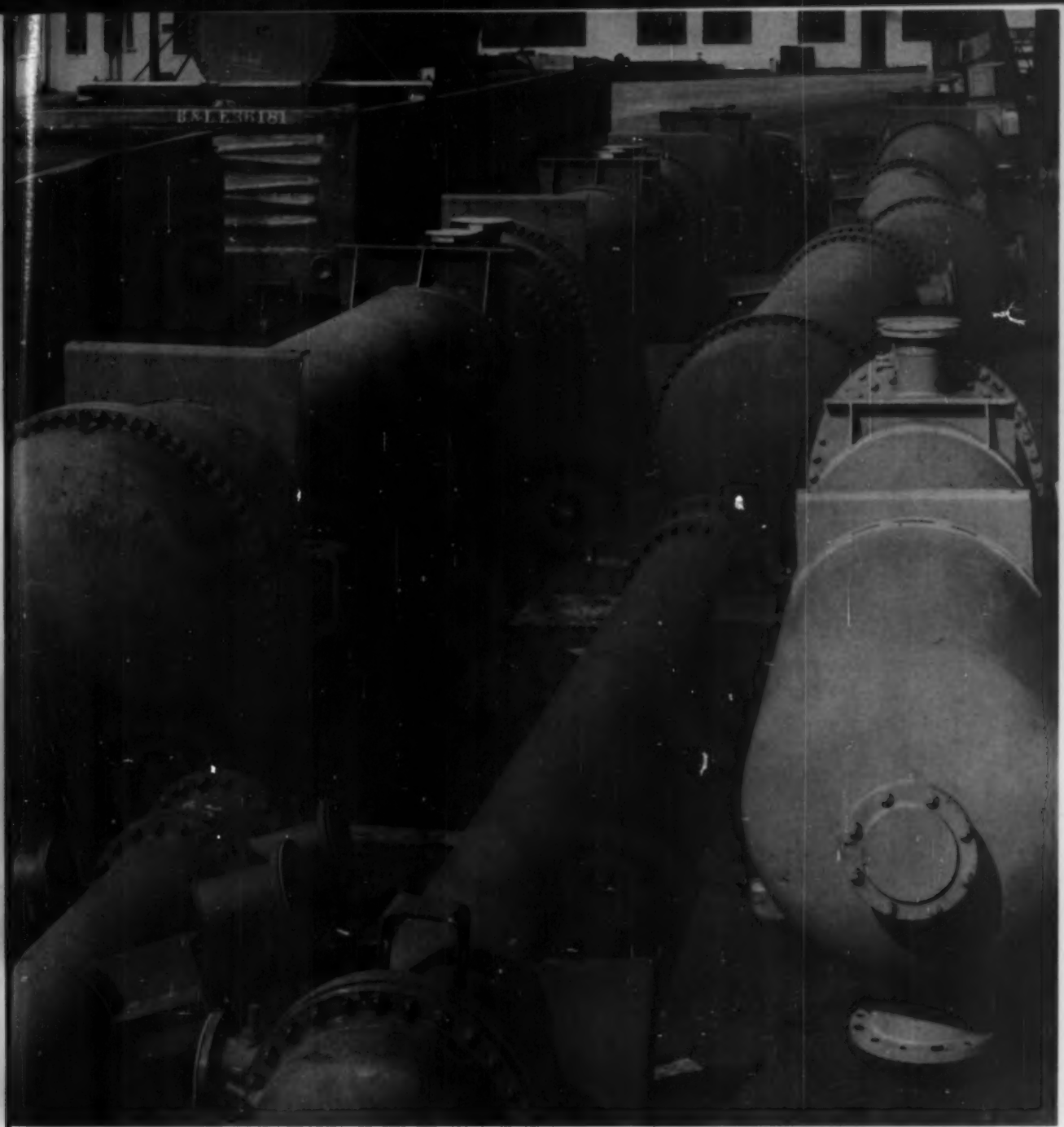
A new SunOlin urea plant at North Claymont, Del., will use the Fauser-Montecatini process, will be engineered by M. W. Kellogg with the technical assistance of Montecatini. Capacity will be 73,000 tons/year of urea prills and crystals for fertilizer applications.

First commercial unit for production of "Polyox" water-soluble resins is on stream at Union Carbide Chemicals' South Charleston, W. Va., plant. Capacity of the unit is said to be more than 1 million pounds per year.

A new basic supplier of fumaric acid has entered the market with start up of Pittsburgh Coke and Chemical's new plant. New techniques researched by the company have made feasible production of fumaric acid using materials from its phthalic anhydride operation, says PC&C.

Sodium-Borohydride SWS (stabilized water solution) has been put on the market by Metal Hydrides Inc. Said to carry the lowest price tag per pound of any commercially available borohydride product, the new material is aimed at chemical processing uses. Suggested applications include production of foaming plastics and silicates, bleaching and stabilizing wood pulps, and treating natural and synthetic textiles.

The carbon dioxide, chlorine dioxide and fire equipment divisions of Cardox Corp. have been acquired by Chemetron Corp.



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The following 4 Pages that appear to be missing are reader service cards and have been removed.

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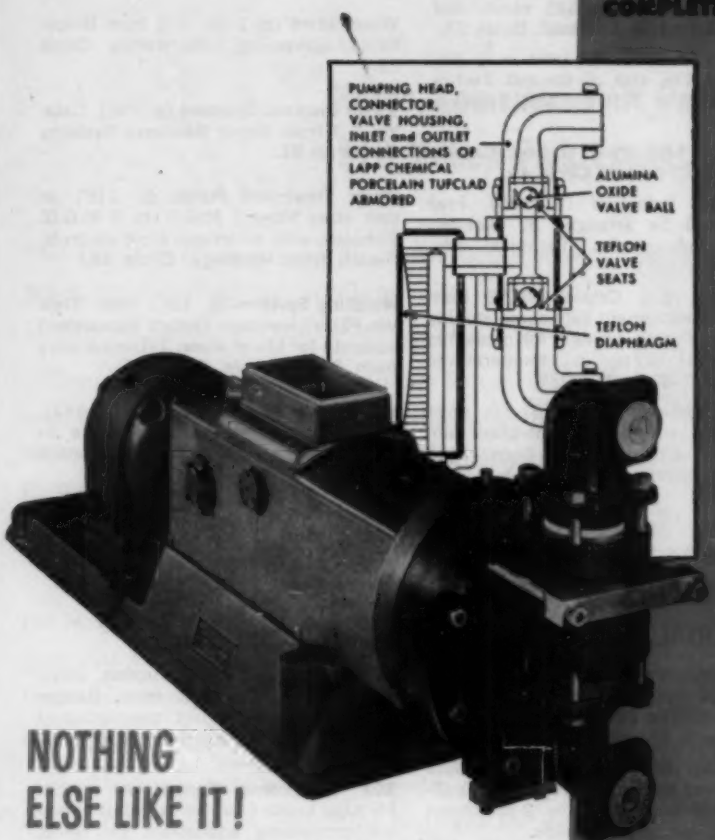
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CEP'S DATA SERVICE—Subject guide to advertised products and services

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD, PAGE 87

Equipment *from page 88*

Pumps, plastic, sealless (p. 139). No stuffing box, no shaft seals, no valves or gaskets. Data from Vanton Pump and Equipment. **Circle 14.**

Pumps, zirconium (p. 141). Leakproof against pressure or vacuum. Details from Eco Engineering. **Circle 22.**

Rectifiers, semi-conductor (p. 30-31). Complete info in Bulletins GEA-6684 and GEA-6375A from General Electric. **Circle 36.**

Refrigeration Units, jet-vacuum (p. 79). Technical details from Croll-Reynolds. **Circle 15.**

Rotameters (p. 139). New Bulletin 18L from Schutte and Koerting gives details of laboratory rotameters. **Circle 73.**

Scrubbers, dust (p. 93). Bulletin from National Dust Collector Corp. gives details of the "Hydro-Filter," capacities from 1 to 40,000 cu. ft./min. **Circle 59.**

Scrubbers, fume (p. 12-13). Standard and custom-built fume scrubbers. Full engineering details from U. S. Stoneware. **Circle 90.**

Scrubbers, fume (p. 32). Bulletin 4R from Schutte and Koerting. **Circle 83.**

Scrubbers, fume (p. 108). Bulletin from Maurice A. Knight gives tables and graphs on capacities, pressure drops, horse-power. **Circle 46.**

Scrubbers, fume (p. 137). Bulletins from Heil Process Equipment describe several designs in standard sizes from 1,000 to 30,000 cu. ft./min. **Circle 40.**

Scrubbers, fume (p. 142). Details on Multi-Wash Collectors from Claude B. Schneible Co. **Circle 82.**

Sedimentation Equipment (p. 26). Bulletin SM-1005 from Eimco covers line of process "Oxidators," clarifiers, other sedimentation equipment. **Circle 23.**

Separators, entrainment (p. 4). In stainless, other materials of construction. Bulletin 21 from Otto H. York. **Circle 96.**

Separators, entrainment (p. 18). High efficiency over entire range of flow. Peerless Mfg. **Circle 61.**

Sifters, rotary (p. 5). Single or multiple separations down to 325 mesh. Bulletin 503 from B. F. Gump. **Circle 33.**

Strainers (p. 149). Available in 2, 2½, 3, 4, and 6 in. size, all flanged. Technical data from Schutte and Koerting. **Circle 74.**

Tanks (p. 149). New 16-page Catalog from Littleford Bros. **Circle 49.**

Television, industrial (p. 133). Free survey will be arranged by Blonder-Tongue Laboratories. Technical info. **Circle 10.**

Valves (p. 10). Catalog 407-S from American Instrument lists complete line of valves, tubing, fittings, for pressures to 100,000 lb./sq. in., temperatures to 1,000°F. **Circle 1.**

Valves, acid-proof (p. 113). In solid chemical porcelain, fiberglass-reinforced. Technical data from Lapp Insulator. **Circle 47.**

Valves, control, diaphragm-operated (p. 154). Catalog from George W. Dahl. **Circle 16.**

Valves, globe, impervious graphite (p. 27). All wetted parts of Karbate impervious graphite or Teflon. Data from National Carbon. **Circle 55.**

Valves, nickel & Monel (p. 95). Complete line for chemical processing needs. Wm. Powell Co. **Circle 64.**

Vibrator, bin (p. 143). Keeps bulk materials moving in bins with small volume of low-pressure air. Details from Bin-Dicator Co. **Circle 7.**

Viscometers (p. 116). Info from Brookfield Engineering Laboratories. **Circle 11.**

Waste Disposal Systems (p. 136). Catalog S-3 from Vapor Recovery Systems Co. **Circle 91.**

Water Treatment Plants (p. 118). In unit sizes from 1 M.G.D. to 5 M.G.D. Complete with automatic plant controls. Details from Hardinge. **Circle 38.**

Weighing Systems (p. 134). New "Flexure Plate" leverage system guaranteed accurate for life of scale. Technical data from Thayer Scale. **Circle 86.**

Wire, thermocouple extension (p. 147). Specifications and technical data in Bulletin 1200-3 from Claud S. Gordon Co. **Circle 30.**

CEP's DATA SERVICE—Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD, PAGE 85

EQUIPMENT

301 Air Washers, industrial. For handling of acids, alkalies, corrosive fumes. Capacities from 1,000 to 54,000 cu.ft./min. Data from Industrial Plastic Fabricators.

305. Btu Meter. A single recorder continuously records, indicates, integrates Btu loss or gain of a flowing liquid. Data from Hays Corp. on new Model 913.

306 Centrifuges, portable. Self-cleaning, disc-type centrifuge develops settling force of 7,800 times gravity. Available also on rental basis. Data from Pfaudler.

309 Compressors, diaphragm. Bulletin 5C from Pressure Products Industries gives performance curves, technical details of new model two-stage diaphragm compressor, particularly suited to pilot plant use.

continued on page 92

MATERIALS

366 Acrylamide, polymerization of. American Cyanamid offers reprint of article on "The Polymerization of Acrylamide with Chlorate-Sulfite Inhibitor."

367 Alkyl Chlorides. Technical Data Sheet gives reactions, properties, applications of butyl chloride, 2-ethylhexyl chloride, iso-decyl chloride.

368 Butenediol. Technical info and samples of butenediol (2-butene-1, 4-diol) available from General Aniline & Film.

369 Butyl Rubber. Two new Bulletins from Thiokol Chemical give resistance of Butyl rubber compounds to ozone and to fire-resistant hydraulic fluids.

370 Catalysts, for polyurethane foams. Booklet from Armour & Co., Chemical Div., describes use of high molecular weight tertiary amines as catalysts in manufacture of polyurethane foams.

continued on page 92

SERVICES

391 Design and Construction, nitric acid plants. Brochure from Badger Mfg. includes flow chart, description of improved process, engineering and construction details.

392 Equipment Rental. A special Package Lease Plan for rental of chemical processing equipment for terms from 3 to 5 years is offered by Nationwide Leasing Co. Detailed info available.

393 Fabrication, process equipment. Bethlehem Foundry & Machine offers facilities for fabrication of all types of custom-built, heavy-duty chemical processing equipment. Bulletins.

394 Modernization Ideas. Allis-Chalmers offers Booklet titled "59 Ideas for Modernization in '59."

395 Technical Data Books. New Catalog of pocket-size technical data books from Lefax Publishers.

LUMMUS

ENGINEERS AND CONSTRUCTORS FOR INDUSTRY

385 Madison Avenue New York 17, N. Y.

LUMMUS AWARDED CONTRACT TO CONSTRUCT ACROLEIN UNIT FOR SHELL CHEMICAL CORP.

Norco, Louisiana Unit Part of Shell's $10 Million-Plus Expansion Program

The Lummus Company has been awarded a contract to construct an acrolein unit for Shell Chemical Corporation at its Norco, Louisiana plant.

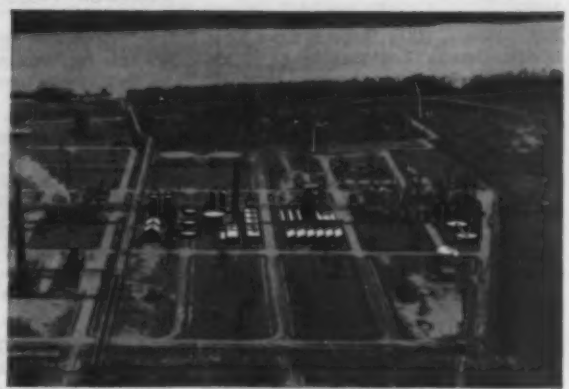
The unit, scheduled for completion late in 1959, is an important part of a program costing more than $10,000,000, which will complete the remaining facilities in Shell Chemical Corporation's current production program at Norco.

The acrolein unit to be built by Lummus will help the Norco plant produce about 35 million pounds of glycerine a year plus substantial quantities of acrolein, a chemical not made in large volume until the development of the present process.

Shell believes that a wider availability of acrolein will lead to a greater variety of end uses for the product, such as plastics and resins, pharmaceuticals, and textile treating.

A second unit in the expansion program will make glycerine, using acrolein from the new unit and hydrogen peroxide from a unit which Shell completed earlier this year.

In addition to the new acrolein unit, other work done by Lummus for the Shell Chemical Corporation includes EPON® Resin Units and a Bisphenol-A Unit at Houston, Texas.



Artist's sketch shows relationship of new acrolein unit to existing plant.

For the design, engineering and construction of plants for the chemical industry, Lummus has over 50 years experience—on over 800 units for process industries throughout the world—to place at your disposal. Call Lummus on your next project.

★ ★ ★

THE LUMMUS COMPANY, 385 Madison Avenue, New York 17, N. Y., Houston, Washington, D. C., Montreal, London, Paris, The Hague, Maracaibo. *Engineering Development Center:* Newark, N. J.

Visit the Lummus Exhibit, Fifth World Petroleum Congress Exposition, New York Coliseum, June 1-5, 1959.

For more information, turn to Data Service card, circle No. 50

CEP's DATA SERVICE—Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD, PAGE 85

Equipment *from page 90*

310 Computers, general purpose. Specifications, basic features, major components, applications described in Bulletin from Royal McBee Corp.

311 Conductivity Equipment. Catalog 23 from Industrial Instruments describes line of electrolytic conductivity equipment for measurement and control of solution concentration.

312 Couplings, quick. Couplings Catalog from Titeflex gives selection chart, flow data, pressure data.

314 Crystallizers. Bulletin from Chicago Bridge & Iron describes its facilities for design, fabrication, and erection of crystallization installations.

317 Detector, holiday. Data from Tinker & Rasor on new design Model M-1 for inspecting thin film coatings for pin holes and voids during application.

320 Feeders, chemical. Bulletin 1140. 20A-1 from B-I-F Industries describes new Model 1140 Proportioneers "Adjust-O-Feeder." Capacity chart with pressure ratings, specifications, dimensions.

321 Filters. Filter Bulletin from Komline-Sanderson Engineering gives details of drum, continuous vacuum precoat, horizontal filters.

322 Flotation Systems. Bulletin SM-1003 from Eimco gives technical details of "Process Flotators" for industrial waste treatment, oil and grease recovery, sludge thickening.

DEVELOPMENT OF THE MONTH

POLYMER LININGS FOR WOOD TANKS

(Circle 602 on Data Post Card)

Wendnagel & Co., manufacturers of wood tanks, announces the introduction of a new type of lining made of various polymers: polyvinyl chloride for handling inorganic acids and bases, bleach, and many organic solvents; polyethylene linings for organic solvents and inorganic solutions. The linings are heat sealed into a bag liner made to fit the inside of the tank. They can be furnished for round or rectangular tanks, new, or already in use. They can be custom-made for special needs or conditions. For a Handbook with test data on these linings, Circle 602 on Data Post Card.

323 Flowmeter, magnetic. New 6-page Catalog 10D1416 from Fischer & Porter gives technical details of obstructionless magnetic flowmeter.

324 Fused Quartz Ware. New Catalog and Price List from Thermal American Fused Quartz.

327 Heat Exchangers, impervious graphite. Bulletin 448 from Falls Industries gives dimensions of standard tube and shell exchangers up to 16 ft. tube lengths, 38 in. shell diameter.

328 Heat Exchangers, plate-type. Bulletin G-560 from Cherry-Burrell Corp. describes complete line for heating, cooling, regeneration.

329 Heaters, plate-coil. Technical Data Manual (Bulletin 159) from Tranter Mfg. on new multi-zone design. Many charts and tables.

330 Heating Units, electric. Custom designed and fitted to your application as to temperature range, input requirements, and area to be heated. Bulletin 158 from Hevi-Duty Electric.

331 Homogenizer. Bulletin from Buschman Products give details of four new models of the "Jet-Mogenizer," capacities from 150 to 500 gal./hr. Lab facilities available for pretesting customer's samples.

332 Instruments. New Index of Literature now available from Minneapolis-Honeywell. Lists product catalogs, specifications, technical bulletins, industry bulletins, instrumentation data sheets.

333 Joints, expansion. Bulletin AD-137 from Garlock Packing gives construction, sizes, and uses of rubber, neoprene, and Teflon-lined expansion joints.

334 Laboratory Glassware. More than 900 new items listed in new supplement to Pyrex Laboratory Glassware Catalog. Corning Glass Works.

335 Manometers. New Brochure on "Manometers—Theory and Applications," from Dynametrics Corp. Conversion tables and working diagrams.

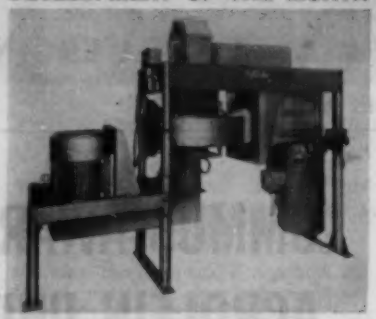
339 Processing Units. Bulletin 575 from Kontro on its line of "Ajust-O-Film" centrifugal processing equipment. For evaporating, distilling, concentrating, heating, cooling, chemical reaction.

340 Processor, digital. Accepts and commutates analog signals, converts them into digital form, records on tape for introduction into standard computers. Bulletin 3004 from Consolidated Electro-dynamics.

341 Processor, laboratory. Rodney Hunt offers Bulletin PE-108 on its "Vacu-Film" laboratory processing unit. Technical details, vapor pressure-temperature chart.

continued on page 94

DEVELOPMENT OF THE MONTH



COUNTER-ROTATING IMPACT MILL

(Circle 601 on Data Post Card)

A new type of impact mill, featuring a counter-rotating action, has been introduced by Entoleter Division, Safety Industries. In Entoleter's conventional impact mill, only the rotor in the center spins, throwing the material to be reduced or dispersed against a stationary outer wall. In the new mill, the outer wall revolves in the opposite direction to the rotor, thus compounding the impact forces at any given rotor speed. According to the manufacturer, this makes possible particle size reduction in the sub-sieve range. The new unit operates at capacities up to 9,000 lb./hr. It is said to be particularly suited for non-abrasive, heat-sensitive organic products such as flour, plastics, etc. For more technical data on this new development, Circle 601 on Data Post Card.

Materials *from page 90*

371 Catalyst, urethane foams. New, 20-page Technical Data Bulletin from Houdry Process Corp. on DABCO (triethylenediamine) for production of urethane foams.

372 Chemicals, research. Catalog titled "Research Chemicals from Dow," lists more than 250 compounds for new product development work. Dow Chemical.

373 Chemicals, research. Twelve methylated compounds and thirteen nitrogen hetero-cyclics offered in development quantities. Folder from Ansul Chemical titled "Chemicals for Research."

374 Chromic Chloride, anhydrous. Samples and technical data available from Diamond Alkali.

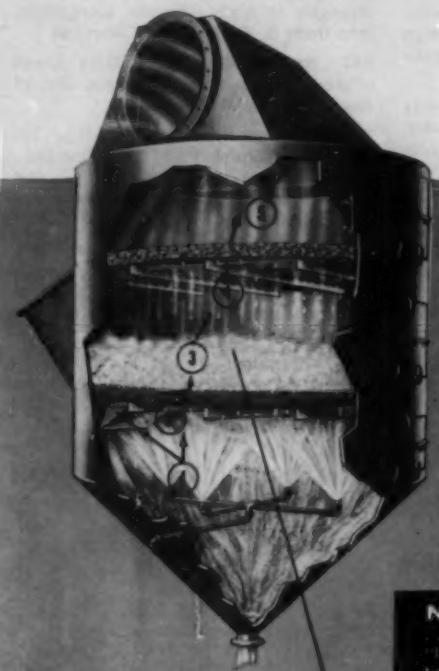
375 Coatings, protective. Bulletins from Xzit Chemical Co. cover protective coatings, other preventive maintenance systems for refineries, chemical plants.

376 Coatings, vinyl wrinkle. Five-page Technical Bulletin from Union Carbide Plastics describes use of vinyl plastisols, organosols, and solutions in formulations of vinyl wrinkle coatings.

continued on page 94

Here's a Dust Collector that cleans itself!

The National Hydro-Filter is an air "scrubber." Dust laden air is brought into contact with water under conditions which cause the dust to transfer to the liquid stream. It differs from conventional wet type dust collecting equipment in several ways —all of which represents radical improvement and assurance of maximum efficiency and low maintenance, over a wide range of operating conditions:



1 Large dust particles are thrown out of the air stream as it changes direction upon entering collector. This portion of the dust load is trapped by contact with the wet surfaces of the conical collection chamber.

2 The air with its remaining dust load starts a torturous, deflective path through the bed packed with glass spheres. Dust is impinged on wetted surfaces and flushed downward continuously.

3 Air is converted to bubbles in pool of violently turbulent water and mist maintained above filter bed. Small dust particles are trapped in water droplets and are flushed downward.

4 Air approaches moisture eliminator bed through more mist and droplets. Entrained moisture is trapped on surface of packing media and returned to the bottom of the collector.

5 Clean air is exhausted to atmosphere.

NO BAFFLES ... to wear, corrode, or "load up" within collection area.

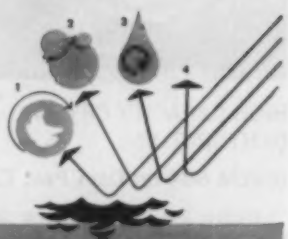
NO INTRICATE PARTS ... to clean. Water action and glass spheres do the work with Hydro-Filter.

NO DEAD AREAS Entire interior is constantly flushed. Every inch is used to collect dust particles.

STOPS DUST 4 WAYS

Four-way particle separation is effected as shown in the diagram at right.

1. *Impingement on wetted surface of glass spheres.*
2. *Impingement on bubble surfaces.*
3. *Entrapment within falling water droplets.*
4. *Impingement on wetted surface of collection area.*



See our advertisement Page 715, Chemical Engineering Catalog or WRITE FOR BULLETIN:

TYPICAL USES

Driers, kilns and coolers • Crushing and grinding • Mixing and bagging • Pickling and plating • Pneumatic and mechanical conveying • Machining and grinding • Boilers • Furnaces and sintering • Incinerators • Foundry

SPECIFICATIONS

- Capacities from one to 40,000 CFM
- Integral or remote fan mounts available
- Uses automatic sludge ejector or cone bottom for continuous discharge
- Corrosion-resistant coating on interior

OPERATION:

Contaminated gas/air is drawn upward through filter bed where it is divided into thousands of small streams which support a turbulent water layer. Intimate gas-water contact insures effective wetting and/or absorption of contaminant. Removal of contaminant is accomplished by continuous backwash action. Upper filter bed removes entrained moisture.

National Dust Collector Corp.

602 Machinery Hall Bldg.
Chicago 6, Illinois

For more information, turn to Data Service card, circle No. 59

CEP's DATA SERVICE—Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD, PAGE 85

Equipment *from page 92*

344 Pumps, high-vacuum. Catalog 90 from Beach-Russ gives specifications, efficiency curves, capacity-pressure curves of new 1,100 cu. ft./min. model.

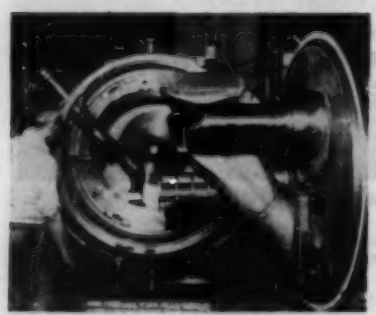
345 Pumps, metering, automatic. Adjusts pumping rate from zero to full capacity on signals from pneumatic instruments. Pressures to 2,000 lb./sq. in. Info from Lapp Insulator.

346 Pumps, nuclear service. New Bulletin from Peerless Pump Div., Food Machinery and Chemical, describes newly-developed pumps for high-pressure and temperature nuclear systems.

347 Pumps, zirconium. New 400 Series GEARCHEM pumps, made by Eco Engineering, claimed to be first mass-produced pump made of zirconium. Flows up to 10 gal./min. Complete technical details.

354 Tubes, heat exchanger and condenser. New Brochure from Bridgeport Brass titled "Solving Corrosion Problems in Industry."

DEVELOPMENT OF THE MONTH



HIGH CAPACITY CRYSTAL DEHYDRATOR

(Circle 604 on Data Post Card)

Twenty-four tons of slurry per hour can be processed in the new Super-D-Hydrator, made by Sharples. The big centrifuge operates at 1,250 rev./min., and the usable power potential that can be applied to the load has been raised to 150 horsepower—an increase of over 100% compared to the largest previous model. At the same time, the diameter of the perforate basket on which the crystal cake is formed has been increased 50%. A number of innovations have been incorporated into the new design. A newly-designed flared feed tube with adjustable nozzle lays a solid layer of slurry evenly across the screen. The heavy-duty cake leveler, which distributes the crystals evenly around the periphery of the bowl to the desired thickness, is activated on both up and down strokes by quick-acting hydraulic piston. The cutting knife is also actuated hydraulically from the central control panel. For complete technical details, Circle 604 on Data Post Card.

355 Tubing, niobium, extruded. Wolverine Tube can accept immediate orders for niobium tubing and rods. Tube from ½ to 1 in. O.D., rod from ¼ to 1 in. dia., lengths to 20 ft. Technical data.

356 Vacuum Units. Bulletin 5H-HS from Schutte and Koerting describes line of "Hydro-Steam" Vacuum Units, includes jet apparatus theory, design features, operation, construction, applications.

362 Valves, plug. Leakproof two-way seal, with round, full pipe area, quarter-turn opening and closing, fully protected seating surfaces. Data from W-K-M, Div. of ACF Industries.

363 Valves, solenoid. Complete Selection Guide and Price List available from Automatic Switch Co.

364 Weighing Units, bulk materials. Unitized pneumatic or electrical systems described in Catalog 12 from Weighing & Control Components, Inc.

365 Weighing Unit, liquid, automatic. Range 1 to 10 lb., output up to 10 weighings per minute. Specially designed for hazardous applications. Details from Glengarry Processes, Inc.

Materials *from page 92*

377 Dimer Acid. New 28-page compilation of patents and journal references on dimer acid offered by Emery Industries.

378 Fatty Amines. Series of Technical Data Sheets from Archer-Daniels-Midland gives reactions, specifications, composition, applications, availability.

379 Fluorine, handling. Booklet from International Nickel titled "Handling Fluorine and Fluorine Compounds with Inco Nickel Alloys." Emphasis on corrosion problems.

380 Hastelloy, alloy C. Booklet from Haynes Stellite gives chemical, physical, and mechanical properties, guide to corrosion resistance.

381 Heat Transfer Medium. Data from Thermon Mfg. on new simplified method for mechanical application of Thermon heat transfer cement.

382 Isobutylene. Petro-Tex Chemical offers a "Family Tree" Chart and Bibliography on isobutylene, giving comprehensive summary of current and potential uses.

383 Lithium, organic compounds. Data Sheets from Lithium Corp. of America give physical, chemical properties, analysis, uses of n-butyllithium in n-heptane solution.

384 Organic Chemicals. Brochure titled "Specifications and Characteristics of Organic Chemicals" from Emery Industries includes metholene fatty acid esters, other new products.

385 Organic Chemicals, physical properties. Comprehensive "Physical properties Booklet" from Union Carbide Chemicals covers more than 400 organic chemicals.

386 Polyurethane Material. New thermo-plastic elastomer, Estane VC, claimed to have extremely high tensile strength at high ultimate elongation. Info from B. F. Goodrich Chemical.

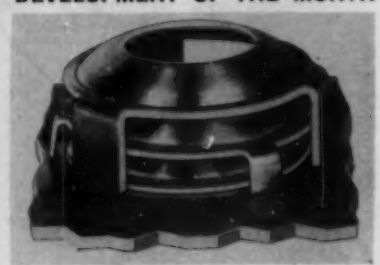
387 Rare Earth Oxides. Data Sheet offered by Research Chemicals, Div. of Nuclear Corp. of America.

388 Silicone Intermediates. New 12-page Data Sheet from Silicones Div., Union Carbide, describes four silicone intermediates, showing reactions and applications.

389 Silicone Rubbers, nitrile. Now available in evaluation quantities is NSR-X5602, first product in General Electric's new family of nitrile silicone rubbers. Technical data.

390 Titanium. Report on Titanium (36-pages) covers properties, corrosion resistance, uses of titanium and its alloys. Harvey Aluminum.

DEVELOPMENT OF THE MONTH



NEW FRACTIONATION TRAY

(Circle 603 on Data Post Card)

A new type of tray, the Glitsch Ballast Tray, is designed around a new type valve unit which acts as a variable orifice to provide multi-staging of the slot area at various rates of vapor flow. A large number of these ballast units, or "metering valves," are incorporated into each tray. According to the manufacturer, Fritz W. Glitsch & Sons, the design of the new ballast unit permits: uniform distribution of vapor through the liquid across the tray over a wide capacity range; optimum vapor velocity through the liquid over a wide range of flow rates; a large turndown ratio by progressive staging of the vapor opening from low to increasingly high flow rates; establishment of a primary pressure drop at the vapor-liquid interface to obtain maximum tray efficiency. For more technical details, Circle 603 on Data Post Card.

A.I.Ch.E. Membership

Brochure—"Know Your Institute"—tells objective aim and benefits to chemical engineers who join this nation-wide organization, includes membership blank. Circle number 600 on Data Post Card.

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THE WM. POWELL COMPANY
Cincinnati 22, Ohio
dependable valves since 1846

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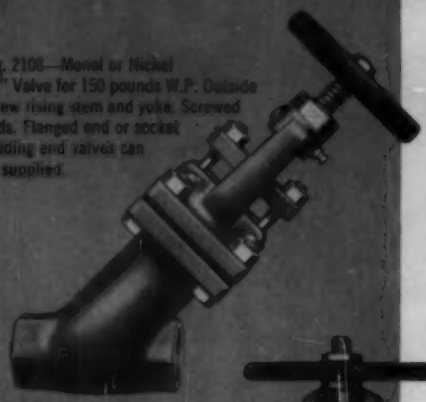

Fig. 2108—Monel or Nickel "Y" Valve for 150 pounds W.P. Outside screw rising stem and yoke. Screwed ends. Flanged end or socket welding end valves can be supplied.

Fig. 2453 SG—Large size O.S. & Y. Gate Valve for 150 pounds W.P. Solid wedge disc. Can also be furnished with split wedge disc. Dimensions conform to latest standards.

Fig. 1836—Monel Metal
Fig. 1839—Nickel
Small Union Bonnet Globe Valve for 200 pounds W.P. Available with screwed, flanged or welding ends; also in angle pattern.

Fig. 1843—Monel Metal, Fig. 1845—Nickel. Small size Check Valve for 200 pounds W.P. Screwed-in cap. Has straightway flow area through valve body when disc is in wide open position. Can also be supplied with flanged or socket weld ends.

Fig. 2493—Bolted flanged bonnet Gate Valve for 150 pounds W.P. Outside screw stem rises through revolving bushing in upper yoke. Interchangeable solid or split wedge discs. Screwed or socket weld end valves also available.

Fig. 1828—Monel Metal
Fig. 1830—Nickel Inside screw rising stem Gate Valve for 200 pounds W.P. Accurately guided solid wedge disc. Also available with flanged or socket weld ends.

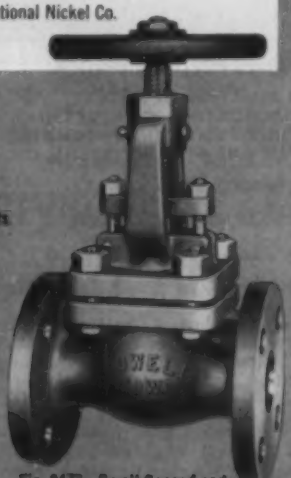

Fig. 2477—Small flanged end, outside screw rising stem and yoke Globe Valve for 150 pounds W.P. Bolted flanged bonnet. Can be furnished with screwed or socket weld ends. Angle Valves available.

For more information, turn to Data Service card, circle No. 64

YOUR FIRST CHOICE –

PULSCO*

NOISE and PULSATION

CONTROL DEVICES

Quiet *that noisy blower with a . . .*

PULSCO SUCTION MUTE®

FOR ALL TYPES OF CENTRIFUGAL BLOWERS, RECIPROCATING COMPRESSORS, ROTARY AND AXIAL FLOW COMPRESSORS.

A. MUTES SUCTION NOISES
B. IMPROVES BLOWER PERFORMANCE WITH LOW PRESSURE LOSS
C. PROVIDES RAIN HOOD PROTECTION
D. INCORPORATES ENTRANCE SCREENS OR FILTERS

Installation of PULSCO Suction Mute on Centrifugal Blower at a Major Oil Company Refinery.

SUBDUES PIPELINE VIBRATION.

FOR ALL TYPES OF ROTARY, RECIPROCATING COMPRESSORS, VACUUM PUMPS AND PNEUMATIC VAPOR AND STEAM SYSTEMS.

1. ELIMINATES METER ERROR.
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4. INCREASES COMPRESSOR EFFICIENCY.

These are but a few of Pulsco products perfected and proved in the fields of pulsation, noise and vibration control.

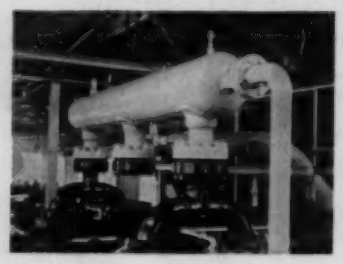
Pulsco representatives are engineers in sound and pulsation control. Feel free to consult them concerning your particular problem.

Your first choice –

PULSCO*

LIQUID *and* **GAS**

PULSE TRAPS*



PULSCO GAS PULSE TRAP
In a west coast gas transmission plant.

PULSATION CONTROLS CORPORATION

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For more information, turn to Data Service card, circle No. 66

industrial news

Increasing demand for ductile vanadium has caused Union Carbide Metals to triple production of this high purity metal. Contributing to the rise in demand are development of nuclear energy uses, a super magnetic alloy, and a titanium vanadium alloy. Expansion in facilities takes place at the Fine Metals and Chemical Department at Niagara Falls, N.Y.

Diversey Italiana, S.p.A., Italian subsidiary, has been acquired by the Diversey Corp. Associates in the new company are Fabbrica Prodotti Chimici, Dott. V. Sacco of Milan, and Saint-Gobain, Chauny and Cirey of Paris. The purchase by the Chicago firm, which also recently acquired Deosan, Ltd., London, is in line with a worldwide expansion policy.

The erection of a carbon black factory in the Netherlands has been assured with the conclusion of a license agreement between Godfrey L. Cabot, Boston, and Ketjen Carbon, Amsterdam, whereby the new Netherlands firm will make use of Cabot's patents and technical knowhow. Production capacity of oil furnace blacks for the rubber industry is planned for 13,000 tons a year. Distribution will be international.

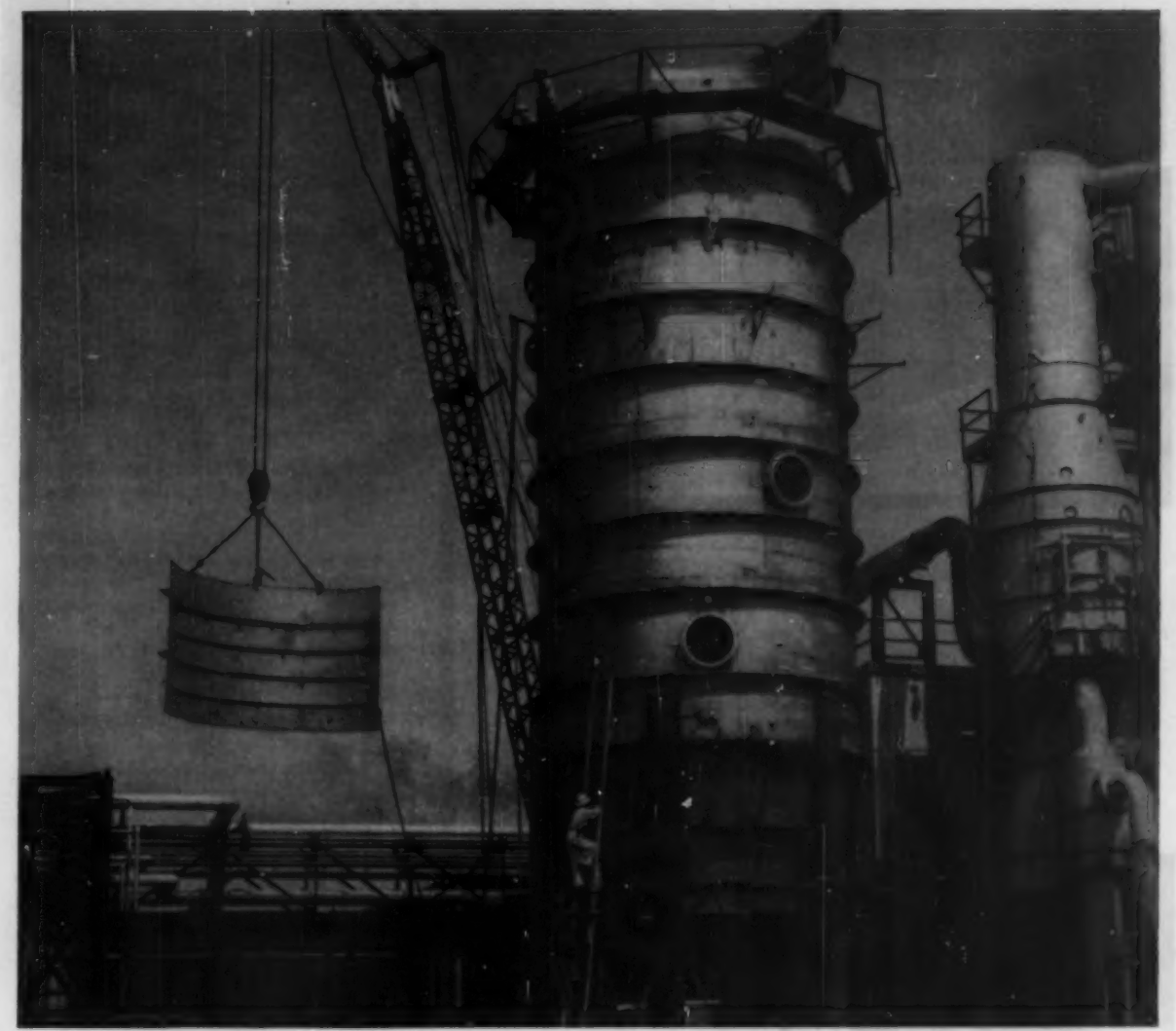
A new source of bauxite for the aluminum industry opens up with the first shipment of Dominican Republic ore to ALCOA's new Point Comfort, Texas, alumina refining plant. Processing has already begun.

Courses for chemical technicians, prepared by the Chemical Institute of Canada, are already in use in some sections of the institute. They consist of junior technician, and senior technician courses. The latter calls for graduation from a recognized institute of technology.

Fome-Cor Corp., jointly owned company formed by St. Regis Paper and Monsanto, to market Fome-Cor, new foamed plastic and paper "sandwich" material.

Production and marketing of tantalum and related chemicals will be handled at National Research by a new department, the Metals Division.

Expansion of chlorosulfonic acid facilities at the William G. Krummich Plant, Monsanto, Illinois, has been completed by Monsanto.



Building the world's largest crystallizer for production of ammonium sulfate fertilizer at the National Aniline Division of Allied Chemical Corporation in Hopewell, Va. The unit was designed and fabricated of Allegheny-Ludlum Type 316 stainless steel by Struthers Wells Corporation of Warren, Pa.

World's largest continuous sulfate crystallizer combats corrosion with Type 316 stainless steel

Nickel-containing Type 316 stainless steel is counted upon to defeat sulfuric acid attack in this huge ammonium sulfate crystallizer. Said to be the world's biggest (150 tons, 82 feet high, 20 feet diameter), the crystallizer will produce about 200 tons of controlled-size crystals daily.

Nickel-containing stainless steels also balk sulfuric acid attack elsewhere in the ammonium sulfate process — pumps, lines, centrifugal separators.

Good hot or cold! Austenitic stainless steels provide ample strength to 1200° F, ample toughness down to –300° F. They resist combinations of heat, abrasion, and corrosion.

In hundreds of chemical processes, the austenitic stainless steels protect such equipment as columns, heat exchangers, holding tanks. When your job involves hard-to-handle corrosives, it will pay you to investigate the lasting qualities of Nickel-containing stainless steels.

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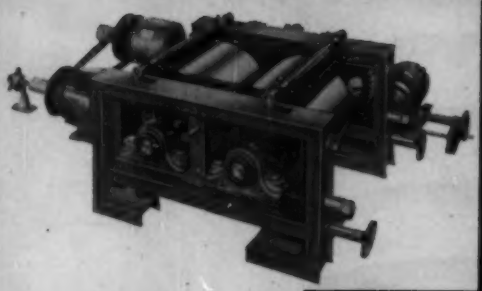

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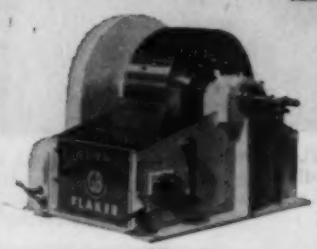
VACUUM ROTARY DRYERS

For heat sensitive products and recovery of solvents. G-B vacuum rotary dryers used for removal of moisture from centrifuged or filtered solids at low temperature levels.



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These pilot scale units, available in our laboratory, provide the means to investigate your process equipment problems and demonstrate performance. Consult G-B for assurance of proper equipment selection.

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For more information, turn to Data Service card, circle No. 35

Industrial news

A four cents a pound price reduction on phthalic anhydride, by Monsanto brings its tank car price to 16¾¢ per pound. Other immediate price reductions are 6 to 13 percent on phthalate ester plasticizers.

A CO_2 recovery unit has begun operation at Finalens Company, Douvrin (Pas-de-Calais), France. Less than 0.1% CO_2 is left in the treated gas, while all the CO_2 is recovered. The installation operates at a pressure of 256 lb./sq. in.

Olin Mathieson Chemical has sold its entire 44% interest in F. H. McGraw & Co. back to that company. According to Olin Mathieson, this transaction marks the completion of its program for disposing of operations and assets not related to its principal fields of activity. Olin Mathieson acquired its interest in F. H. McGraw three years ago in connection with the construction of its aluminum facilities in Ohio and Louisiana.

A $150,000 contract to build a pilot plant for conversion of salt water to fresh by a direct-freeze process has been awarded to Carrier Corp. under the Government's saline water conversion program. Preliminary laboratory work is said to have demonstrated technical feasibility and economic promise.

Terminal facilities for 50% caustic soda will be established by Dow Chemical at the Associated Sales and Supply Co's public terminal in St. Louis.

About $3 million will be spent by Champlin Oil and Refining for modernization and expansion at their natural gas processing plant in Nueces County, Texas. The program will provide for upgrading of all products, increased production of ethane, butane, and propane. Engineering and construction will be by Fluor Corp.

The nozzle for Kiwi-A—the first reactor designed to study feasibility of nuclear rocket propulsion—has been delivered to AEC's Nevada Test Site by Rocketdyne. Most difficult problem overcome in development of the nozzle, which began in August, 1957, is said to have been design difficulties posed by the complex heat loading involved.

Teflon-lined pipe helps plant save $60,000 per month... *enables corrosive process to stay on stream*

Problem: Excessive maintenance costs and product losses ran as high as $60,000 per month during first six months' operation of process at a major chemical plant.

The process for the manufacture of a chemical intermediate involves handling hydrochloric acid and organic liquids at temperatures exceeding 275°F. In the past, the highly corrosive properties of this combination had restricted material of construction to non-metallics.

Laboratory work established that many potential advantages could be obtained by increasing operating pressure from a normal level up to several atmospheres. However, a new material of construction would be required for the high pressure service.

An exhaustive search for satisfactory piping materials included a number of alloys, plastics, and other types of materials. The most promising of these were installed. In spite of this program, such frequent failures occurred that on-stream time averaged only 75% during the first six months' period of operation.

Solution: It was found that two experimental lengths of steel pipe lined with Teflon TFE-fluorocarbon resin had been placed on test previously. Both had provided excellent service for 24 months at 230°F and 10 psig. Both were then reinstalled in the new pressure system and were in operation for several more months without failure.

Based upon this and other encouraging results, conversion to steel pipe lined with TFE resin began as soon as it became commercially available. Plant now has more than 1500 feet of the lined pipe in service. Most of it is of 2" size although some up to 6"in diameter is in use. More than 400 Teflon TFE-fluorocarbon lined fittings are in use at the plant.

Results: No failures of the lined pipe have occurred. Some of it has already been in service more than 15 months. Outstanding performance of the lined pipe under the severe conditions has been a major factor in saving the $60,000 per month that was being lost through excessive maintenance and loss of product. Use of the lined pipe promises to make the process as reliable as those with no special materials of construction problems.

NOW OVER 2 YEARS

In the petroleum industry, pipe lined with Teflon has been found to be quite useful for handling hydrofluoric acid at elevated temperatures and pressures. Lined pipe has also proved valuable in chlorination, sulfonation, and nitration processes. Method used by manufacturer for lining pipe compensates for thermal expansion of liner to the extent that fatigue problems and reduction in flow diameter are eliminated.

(Fluoroflex-T pipe and fittings lined with TFE-Fluorocarbon resin are manufactured by RESISTOFLEX CORPORATION, Woodland Rd., Roseland, N. J.)

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Complete systems for corrosive service

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See the best in Teflon at the Resistoflex booths #2, 3, 4 at the NACE Show in Chicago.

For more information, turn to Data Service card, circle No. 71

Price reductions made headlines

Teflon will cost from 8 to 10% less in all grades, says Du Pont's Polychemicals Dept. Effective last month (February), granular molding powders will be cut 40¢/lb., aqueous dispersions 45¢/lb., and extrusion powder 80¢/lb. Cuts are attributed to a "major breakthrough in manufacturing technology."

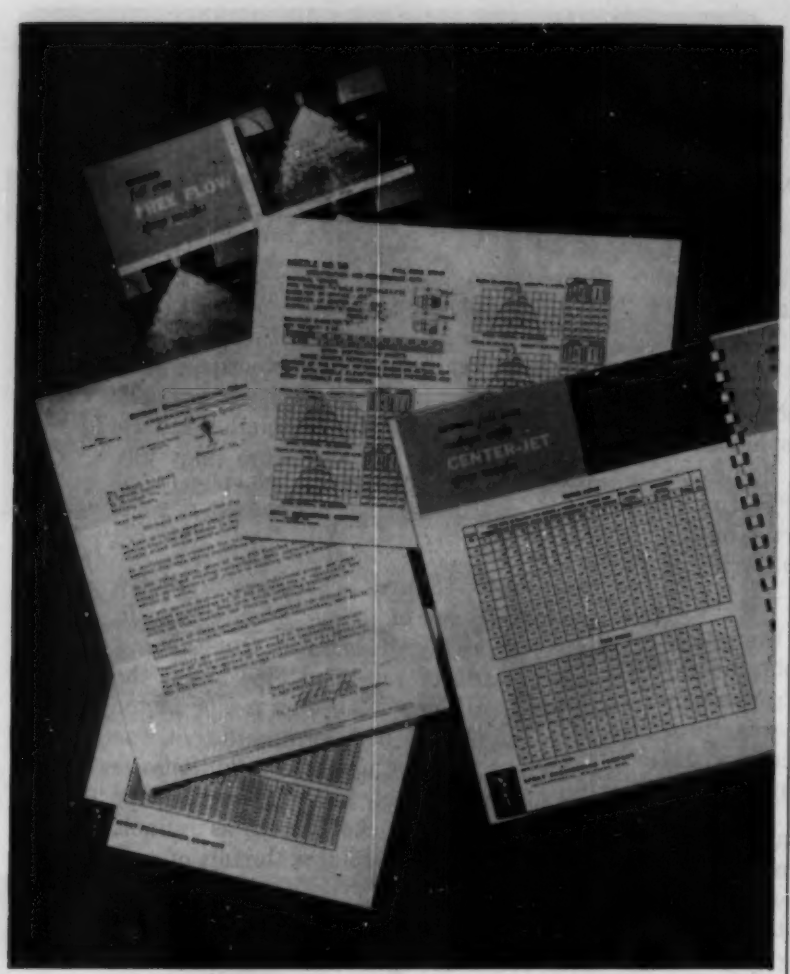
Polypropylene will cost 7¢ lb. less, announces Hercules Powder, at the moment the sole U.S. producer. Natural "Pro-fax" molding powder will cost 4¢/lb., colored "Pro-fax" 51¢/lb. (truckload lots).

Rubber grade styrene monomer will cost 7/10¢/lb. less, says Monsanto Chemical, effective April 1, 1959. New base price will be 12¢/lb. Declining market price of benzene, major styrene monomer raw material, is seen as a large factor in the price reduction.

Chemical derivatives of the less common metals will be emphasized by Electro Metallurgical Co., which has just changed its name to Union Carbide Metals Co. New products include anhydrous metal chlorides and oxychlorides intended as intermediates for production of other metal derivatives. Such compounds have been coming to the fore as catalysts in the rubber and plastics industries, particularly in production of polyolefins. Other metal chemicals soon to go into pilot plant production are finely-divided metal oxides, metal carbonyls, organic derivatives such as esters and acetyl-acetonates, and metal salts, says the company.

Production capacity for tolylene diisocyanate chemicals has been stepped up by 50% at the New Martinsville, W. Va., plant of Mobay Chemical. Urethane foams, elastomers, industrial paints, and wire coatings are counted on to absorb an increasing amount of the basic urethane chemicals.

"Super" insulations for cryogenic service, up to 26 times more efficient than standard vacuum insulations, are claimed by Linde (Union Carbide). Details of the new system, said to have resulted from a "new concept," have not been disclosed, but may well be a refinement of the powder-vacuum system introduced by Linde in 1946.



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Here's a surer, easier way to specify spray nozzles

How can you be sure you're specifying the *right* spray nozzle for your particular application?

Spraco's research department has taken the guesswork out of this problem by preparing complete and accurate performance data for each of the hundreds of spray nozzles in the Spraco line. Each nozzle "profile" is complete with data on material, dimensions, flow rate, pressure, angle of spray . . . everything you need to enable you to choose, at a glance, the nozzle that will deliver maximum performance and efficiency in your particular application.

No matter what your spray nozzle problem, Spraco makes this information available to you absolutely free. Why not write and ask about it — today?

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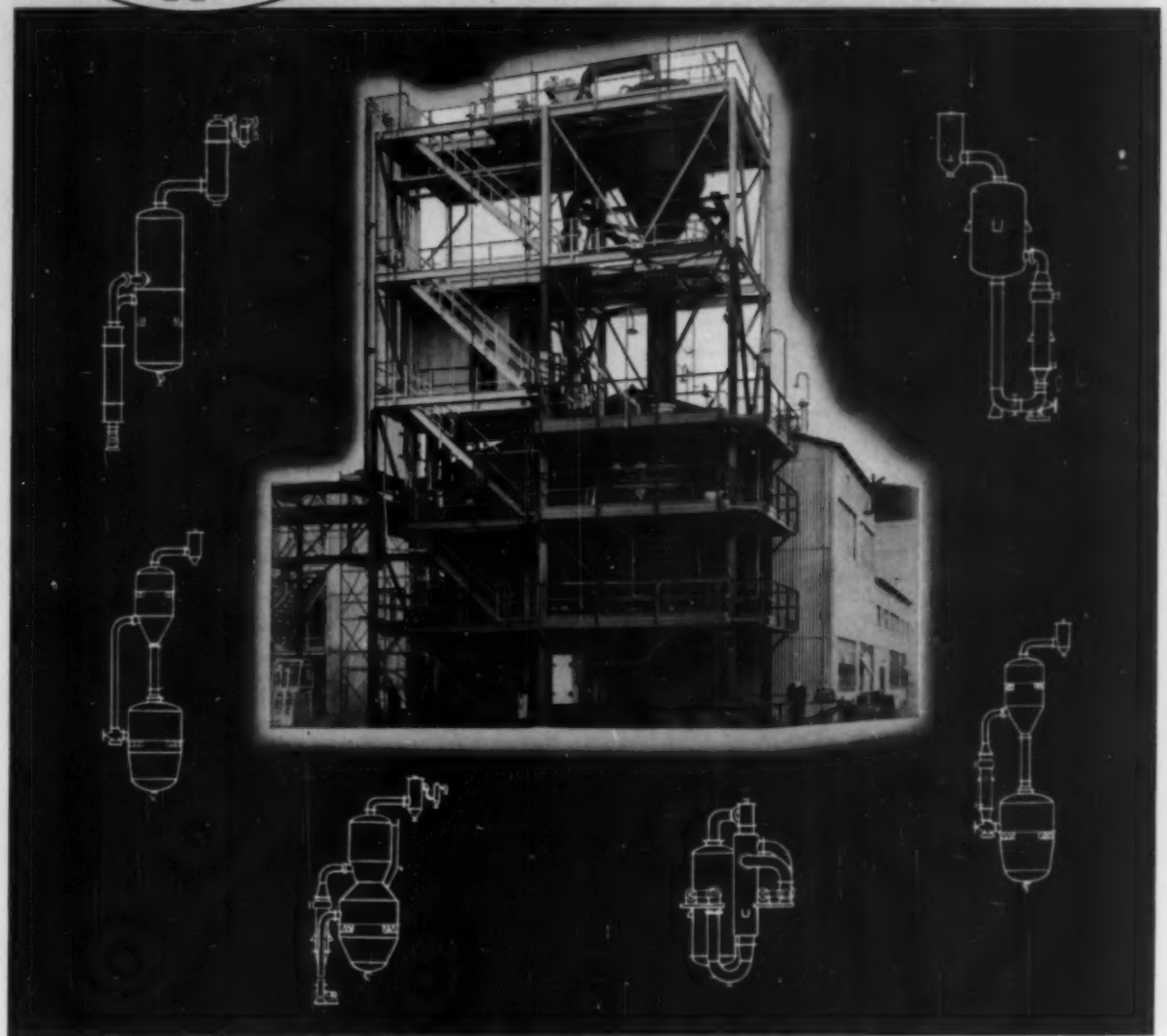
Struthers Wells

Our experienced engineers will be pleased to co-operate with you on any crystallization problem



Crystallizers* of All Types...

Know-how, combined with laboratory and pilot plant equipment, plus the finest manufacturing facilities enable us to offer the designs best suited for specific purposes.

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Formerly MICRO REPAIR COMPANY, Moorestown, N. J.,
makers of repair parts to original specifications.

For more information, turn to Data Service card, circle No. 41

industrial news

A course in "Engineering Kinetics" will be presented by R. H. Wilhelm of Princeton in April, at the 12th annual *Lectures in Science and Engineering*, sponsored at Baytown, Texas, by Humble Oil & Refining Company. This is part of three remaining graduate level courses of a series of six for the 1958-59 season.

A 5,000-kilowatt pressurized water reactor will be built by Westinghouse for the General Public Utilities system for use at a power station now in operation near Saxton, Pa.

A nuclear reactor engineering course is being established at Lehigh University as part of the chemical engineering curriculum. Included will be studies in neutron diffusion in the sub-critical reactor, liquid-metal heat transfer, nuclear fuel properties and processing.

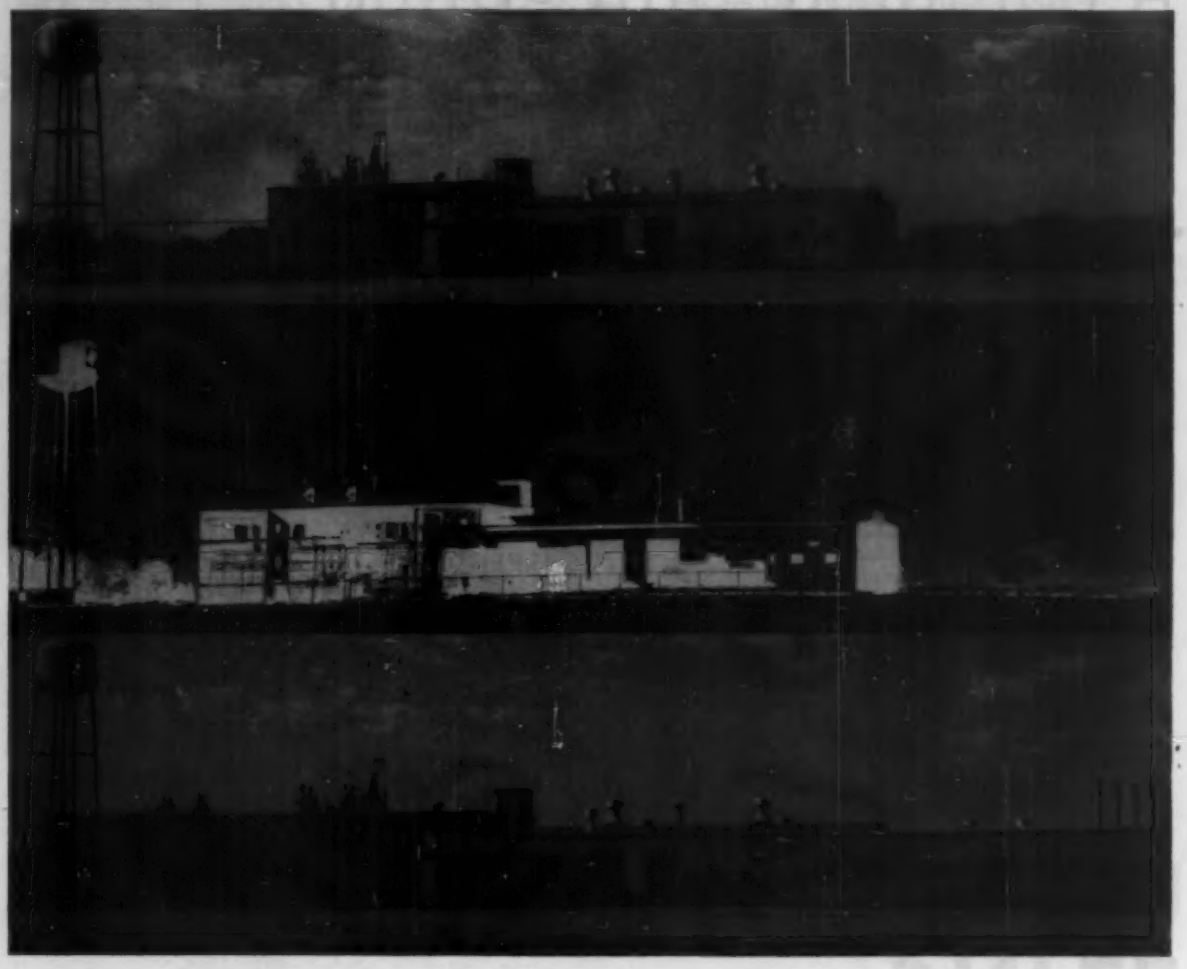
Manufacturing and laboratory facilities of the Anderson Chemical Co. at Weston, Mich., will be expanded at a cost of about $200,000. The company is a division of Stauffer Chemical, and the project will be handled by Stauffer's engineering staff.

Lithium aluminum hydride production will be doubled at Metal Hydrides, Inc., Beverly, Mass. The expansion, says MHI, is in response to increasing demand for the alumino hydride in hormone synthesis, vitamins, other pharmaceutical products.

Modification and expansion of the Eunice, La., gasoline extraction plant owned jointly by Runnels Gas Products Corp. (subsidiary of Union Oil and Gas) and Texas Gas Exploration Corp. will be carried out by Fluor Corp. at a cost of about $500,000. Natural gas capacity will be upped by 69 million cu. ft./day to a total of 369 million cu. ft./day.

Four courses in plastics technology will be offered starting January 5, 1959, by the Special Courses Division of Newark College of Engineering, in cooperation with the Society of Plastics Engineers, Newark Chapter. Courses will comprise: Compression and Transfer Molding; Plastic Mold Design; Thermoplastic Process Techniques; and Testing and Control of Plastics Properties. The courses may be taken individually or as part of a full three year certificate program.

BK *Blaw-Knox built them all*—starting with National Starch's original plant, and continuing with the design and construction of two successive expansions. Responsibility included all buildings, process equipment and utilities.



at Meredosia, Illinois

National Starch increases polyvinyl acetate production 200% in three years

In 1955 a new plant . . . by spring of '56 an expansion that doubled capacity . . . today a second expansion that will again double original capacity.

In all of this dynamic growth National Starch and Blaw-Knox have been building together. From the first, owner and contractor formed a smooth working team as they erected the original plant. This same team was put to work again and again as National Starch retained Blaw-Knox to design and build two plant expansions.

It is the winning combination of men solving problem after problem that has kept all the projects moving ahead on schedule.

To learn how Blaw-Knox's broad experience and technical resources can help you with a process, a new facility, or plant modernization or expansion, contact Blaw-Knox Company with headquarters in Pittsburgh, branch offices in New York, Chicago, Haddon Heights, New Jersey, Birmingham, Washington, D.C. and San Francisco.

plant builders for industry... BLAW-KNOX

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(PRESSURE TYPE)

FE INC® CONTINUOUS FILTERS

Custom Engineered

- VACUUM OR PRESSURE ROTARY DRUM
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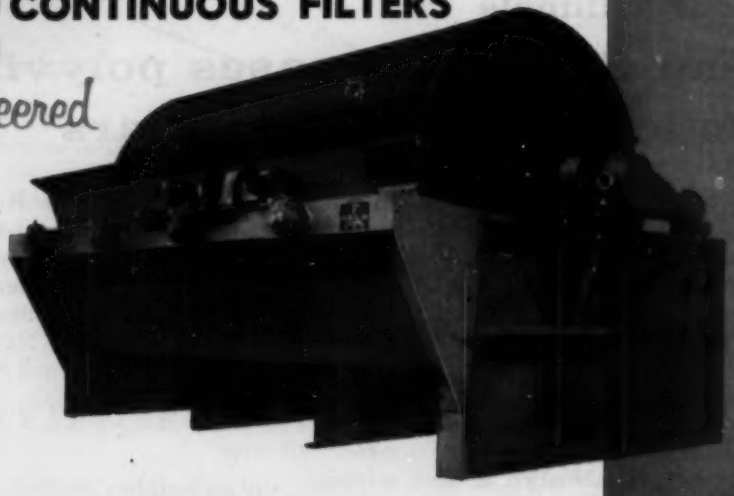

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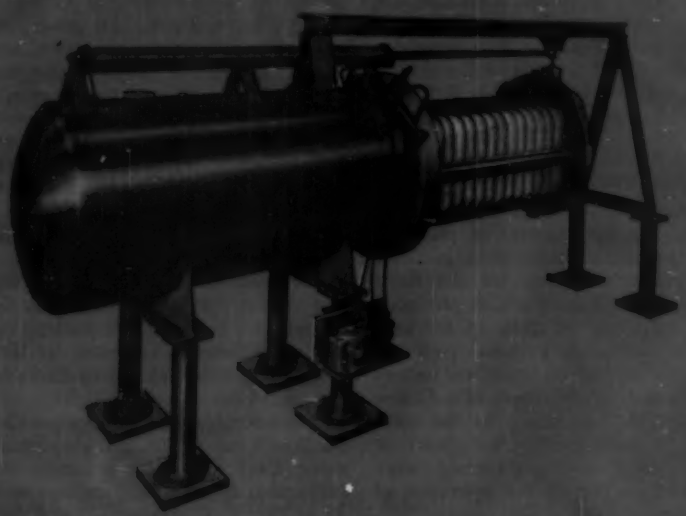

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A Case History of In-Plant Air Pollution Control

Before and after case history study of dust control progress in a metallurgical plant shows many of the pitfalls, describes solutions that added up to a multi-million dollar investment.

The Ashtabula, Ohio, plant of Electro Metallurgical Company (Union Carbide) was a war baby. Built at the Government's request, the first furnace went into operation in June, 1943: by the end of that year, six alloy and three carbide furnaces were in full blast turning out ferro-alloys and calcium carbide. An essential and successful operation—but, due to lack of critical materials in war time, the Government's plans had made only a minimum allowance for dust control systems.

In 1946, Electromet purchased the plant from the Government and, almost immediately, embarked on a major expansion program to meet an ever-increasing demand for alloys and calcium carbide. A new steam power station (doubled in capacity starting in 1951), was followed by construction of new lime kilns, an acetylene generator house, and by significant expansion of existing facilities.

Dust-control studies were begun soon after Electromet acquired the plant in 1946. First problem to be attacked was the collection of fly ash from the steam-plant stack. At a cost of some $150,000, mechanical collectors of a centrifugal type were installed. Performance, however, fell far short of the efficiency required and it was decided to go over to electrostatic precipitators, in addition to the mechanical collectors. Four such precipitators have been put into service—cost: about $1 million. Efficiency is claimed to be approximately 97%, well above the 93% specified by the ASME code.

Process Change

Prime example of in-plant process change for the purpose of pollution control was the substitution, in 1948, of vertical lime kilns for the then-standard rotary kilns which produced large quantities of dust. In the new vertical kilns, the gases pass up through the bed of limestone instead of over it as in the rotary kiln. Cost—considerable, according to the company, in addition to five years of development and engineering work required to perfect the operation of the vertical kilns.

Covers plus scrubbers

Fifteen covers and fume scrubbers installed on carbide and alloy furnaces between 1950 and 1956 are claimed to remove about 98% of all dust emitted from the furnaces. A cover (see illustration) extends over the entire top of the furnace, except for electrode openings. It is made of heavy steel plate, and is cooled by circulating large quantities of water through all sections. Hot gases are withdrawn from under the cover, and passed through a large high-speed centrifugal scrubber equipped with a series of water sprays. Cost—approximately $2 million for the fifteen covers and scrubbers, including research, development, engineering, and construction.

Cyclone separators have been installed to handle the dust problem arising from all coke crushing, sizing, and drying operations, and from the carbide mix handling and packing operation. Efficiency is stated as 99%; the dust is collected in bag filters for disposal. Cost—about $400,000.

Three scrubbers have been installed on lime kilns in the carbide department. Each scrubber can handle 60,000 cubic feet of air a minute with an efficiency of between 95 and 98%. Dust-laden gases from the kilns are passed up through 22 sets of water spray nozzles; the dust and water form a sludge, which is pumped out to a settling basin. Cost — about $140,000.

Electromet estimates, that up to early 1958, it has spent approximately $6 million on its smoke-abatement program.

Before and after—Furnace cover and scrubber system at Electromet's Ashtabula plant, showing the effectiveness of dust collection method said to be 99 percent efficient.

TOWER PACKING

All the facts about HARSHAW *tellerettes*

Contained in this comprehensive booklet discussing the application of Harshaw Tellerettes to tower packing.

Subjects discussed at length (accompanied by pertinent charts)

1. The Tellerette Shape
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For more information, turn to Data Service card, circle No. 39

Photo Courtesy Summerill Stainless Tube Div.

—absorb acid fumes and mist; remove dust; cool hot gases

Knight Fume Washers can be built to handle gases or fumes of nearly every character. The one above is removing nitric-hydrofluoric acid fumes which come off pickling tanks that are processing stainless steel tubes. The fumes enter the washer where they are neutralized with a 10% caustic soda solution. Berl Saddle packing, the operating heart of the tower, provides large liquid film areas in the gas stream. This makes for efficient fume washing with relatively small sized equipment.

Knight Fume Washers are designed for many other types of corrosive service, such as absorption of HCl fumes, suppression of oil and acid mists, removal of dust from exhaust gas, elimination of chlorine fumes, and cooling hot gases for processing.

Write today for Knight Bulletin No. 90 on Fume Washers, which gives complete data on their construction and operation. It has tables and graphs showing capacities, pressure drops and horsepower requirements.

MAURICE A. KNIGHT

Acid and Alkali-Proof Chemical Equipment

7 Kelly Avenue Akron 9, Ohio

For more information, turn to Data Service card, circle No. 46

Safe power from strontium

Prospects for solution of the problem of transforming Strontium 90 into a safe source of additional power are looking up. A ground-based 100-watt generator, fueled by a compound of Strontium 90 and designed to operate for almost a decade without servicing, is under development at the Martin Company Nuclear Division, Baltimore, Maryland. The final generator will use about 200,000 curies of Strontium 90, will be similar in principle to "SNAP III," thermoelectric device demonstrated recently at the White House.

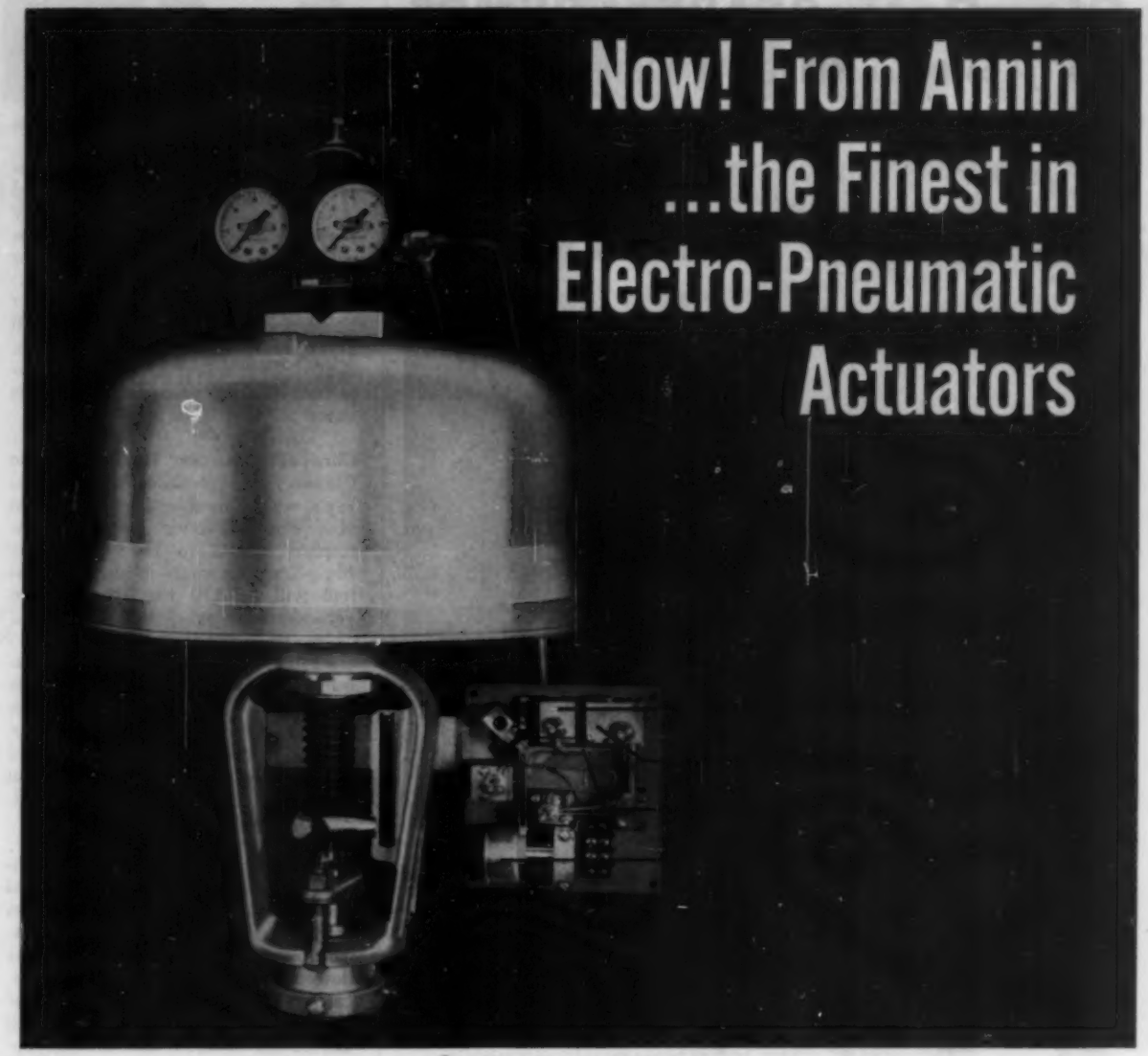
Officials of the company feel that radioactive danger can be eliminated by "locking" the radioisotope safely inside an insoluble compound at the core of the generator. While experiments thus far have been limited to non-radioactive Strontium 90, several compounds are now being studied, including Strontium Hexaboride. The hexaboride remains solid up to 2,235°C, and its insolubility is such that crystals are normally washed in boiling hydrochloric and sulfuric acids as part of the refining process.

An additional safety factor would be provided by sealing the Strontium compound in corrosive-resistant capsules inside a massive heat sink.

Work proceeds under the direction of the AEC's office of Isotopes Development.

A $10 million fertilizer plant is scheduled for the Northwest by July, 1960. Annual capacity will be about 200,000 tons of fertilizer products. Owner will be Bunker Hill Co., a major zinc and lead producer with metallurgical plants at Kellogg, Idaho, and fabricating and chemical products divisions in Seattle, Washington. Sulfuric acid for the fertilizer project will come from conversion of waste gases from the company's metal reduction operations at Kellogg. Present acid production by this route is 100,000 tons/year, more conversion facilities are planned, says Bunker Hill. Exact site of the projected plant has not been fixed.

A new phenol plant has been completed at Iwakuni City, Japan for Mitsui Petro-chemical Co. The unit uses the Distillers Co. Ltd. process, design and engineering supervision was by Stone & Webster.



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Annin's Model 30,000 transducer, coupled with the Annin Domotor, gives you greater range of adjustment, unequalled stability, and exceptional dynamic characteristics

The Model 30,000 has been developed to provide process engineers with a practical transducing element for converting a small electrical signal to an accurate and stable pneumatic output pressure. It embodies only four basic sub-assemblies, which minimize motion and wear, simplify adjustment and installation. The Model 30,000 features full-scale zero adjustment and a wide range of span settings for split range and sequencing applications. Absence of complex components, together with minimum installation,contribute to low maintenance. Linearity and accuracy reach a new high in electro-pneumatic transducing with the Model 30,000. *Technical data on request*

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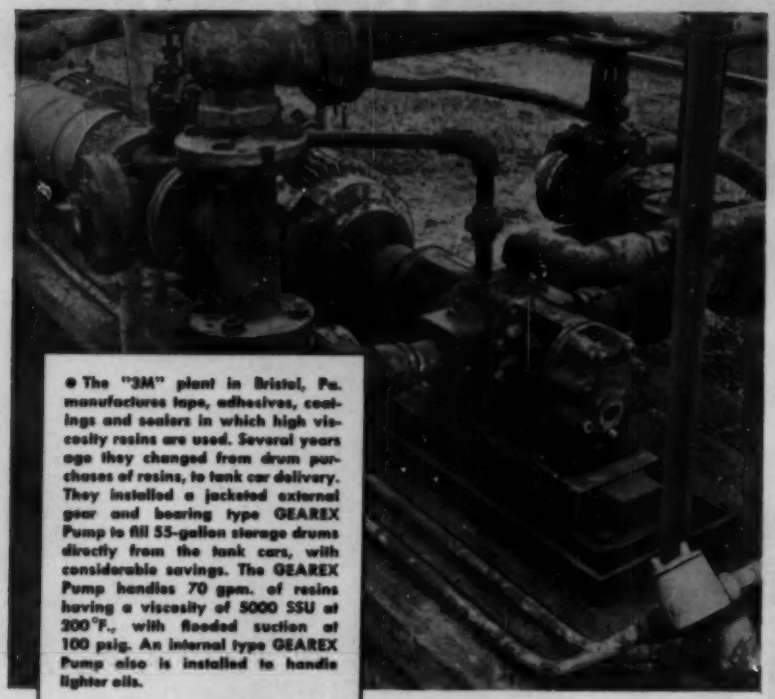
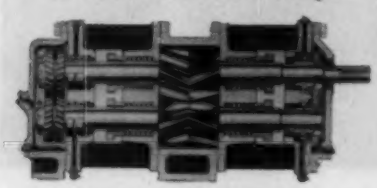
Sier-Bath GEAREX® PUMPS

help cut costs for MINNESOTA MINING & MFG. CO. in tank car-to-drum pumping of heavy resins

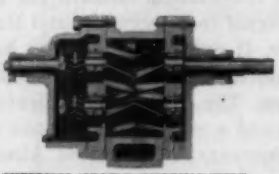


● The "3M" plant in Bristol, Pa. manufactures tape, adhesives, coatings and sealers in which high viscosity resins are used. Several years ago they changed from drum purchases of resins, to tank car delivery. They installed a jacketed external gear and bearing type GEAREX Pump to fill 55-gallon storage drums directly from the tank cars, with considerable savings. The GEAREX Pump handles 70 gpm. of resins having a viscosity of 5000 SSU at 200°F., with flooded suction at 100 psig. An internal type GEAREX Pump also is installed to handle lighter oils.

Sier-Bath "Gearex" Pumps



EXTERNAL GEAR & BEARING TYPE
for non-lubricating liquids



INTERNAL GEAR & BEARING TYPE
for lubricating liquids

Sier-Bath "Gearex" Pumps provide positive displacement, pulseless flow . . . quiet, vibrationless operation. Direct-connected up to 1800 RPM, they require no reduction gears. For high volumetric efficiency and long life there is no rotor-to-rotor or rotor-to-casing contact. Low pressure on stuffing boxes provides easy servicing.

Horizontal or vertical models to handle 32 to 500,000 SSU, 1 to 550 GPM at 250 PSI for viscous liquids, 50 PSI for water. Corrosion-resistant alloys, steam-jacketed bodies, water-cooled bearings, other adaptations to meet individual needs. See "Yellow Pages" for your local Sier-Bath Pump Representative or send for Bulletin G-2. *Sier-Bath Gear & Pump Co., Inc., 9272 Hudson Blvd., North Bergen, N. J.*

Sier-Bath ROTARY PUMPS

Screw Pumps | Gearex® Pumps | Hydrex® Pumps

Founded 1905 — Mfrs. of Precision Gears, Rotary Pumps, Flexible Gear Couplings — Member A. G. M. A.

For more information, turn to Data Service card, circle No. 75

industrial news

A new affiliate, Blaw-Knox Engineering Co., Ltd., with headquarters in London, is announced by Blaw-Knox. "Growing overseas demand for consultation, design, engineering, and construction services" is cited by Blaw-Knox as the motivating factor behind the establishment of the new company.

Ethylene and propylene capacity will be expanded by 40% at the Spondon, Derby, plant of British Celanese. Completion of the expansion program is slated for mid-1959.

Corn oil extraction facilities at the Clinton Corn Processing Co., Clinton, Iowa, will be increased by installation of a "Rotocel" continuous solvent extraction system to be supplied by Blaw-Knox. Capacity of the new system will be 170 tons/day of corn germ (expeller cake).

Operation of eight natural gas extraction plants, formerly operated by Arkansas Louisiana Gas Co., has been taken over by a newly-formed subsidiary, Arkansas Louisiana Chemical Corp. Chlorine and caustic production began in October at the Pine Bluff, Arkansas plant.

Four million pounds per year of ammonium perchlorate will be turned out in a plant now under construction by HEF, Inc., near Columbus, Miss. The plant, which uses a new process developed jointly by Hooker Chemical and Foote Mineral, owners of HEF, is said to be capable of being shifted over without difficulty to production of lithium perchlorate, should this be demanded by the missile program.

Expansion plans at Du Pont include a low pressure polyethylene plant to be completed by mid-1960 at its Sabine River Works, and a 30% increase in capacity for "Mylar" polyester film to be ready for operation early in 1960 at the company's Circleville, Ohio, facilities.

A new type of corrosion and heat resistant stainless steel is announced by Armco Steel. The new alloy, Armco 22-4-9, is designed for service at temperatures from 900 to 1,600 F. in such applications as high-temperature steam valves and gas turbine parts. Despite its low nickel content (3-5%), it is said to remain completely austenitic under all conditions.

FLUIDICS

is a Pfaudler Permutit program providing
the know-how
the equipment
and the experience
for solving problems involving fluids.

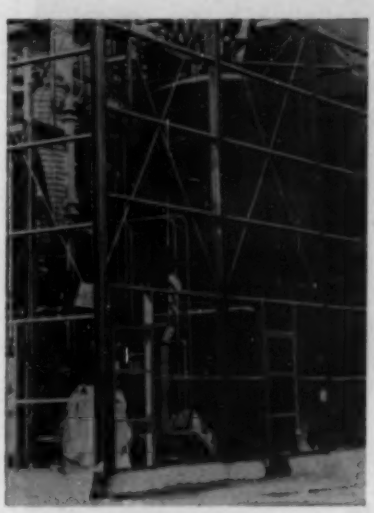
FLUIDICS covers such varied phases of fluid handling and control as:

corrosioneering
water treatment
waste treatment
reactions
polymerization
ion exchange
fluid analysis, metering and control
agitation
evaporation
distillation
drying
blending
metering
valving
flow rate control
piping
storing
centrifuging
filling
heat transfer etc.

Whenever you have a fluid-handling problem, look to this Pfaudler Permutit FLUIDICS program for the best solution.

PFAUDLER PERMUTIT INC.

Specialists in FLUIDICS . . . the science of fluid processes



FLUIDICS AT WORK

Glasteel takes the bite out of chlorine dioxide

Chlorine dioxide generation is an excellent example of the depth of our FLUIDICS program. Here is a highly corrosive material made from other corrosives in a complex process.

The chemicals commonly used have no corrosive effects whatsoever on Glasteel—sodium chlorate, sulfuric acid, and methanol in the Solvay process; sulfur dioxide, sulfuric acid, and sodium chlorate in the Olin Mathieson process.

An even more important factor here is the sheer versatility of Glasteel. You can use it wherever corrosives are present . . . everywhere from generators to storage tanks to pumps to pipes, fittings, and valves.

More than 25 pulp and paper mills are now using Glasteel equipment from Pfaudler for chlorine dioxide generating processes. And, when they do a complete cost analysis covering original prices, maintenance costs and long range equipment life, they find Glasteel the most economical equipment they can use.

FLUIDICS AT WORK

Now, a packaged centrifuge for in-plant production line testing

So that you can test our Titan centrifuge with your own products in your own production line, we've mounted a 6,000 gal./hr. capacity unit on a movable skid that is completely integrated with the required pumps, valves, controls, and other accessories.

All you need is an available 220/440 three-phase electrical service and you're in business.

This first of a series of packaged test units is available on a leasing agreement set to meet your particular needs.

They supplement a test program which has operated for some time now in our Pfaudler labs. They should prove of great value where you have products that are perishable or otherwise difficult to ship or whenever you prefer to do your own in-plant testing.

We will also provide technical personnel for setting up and operating the test program.

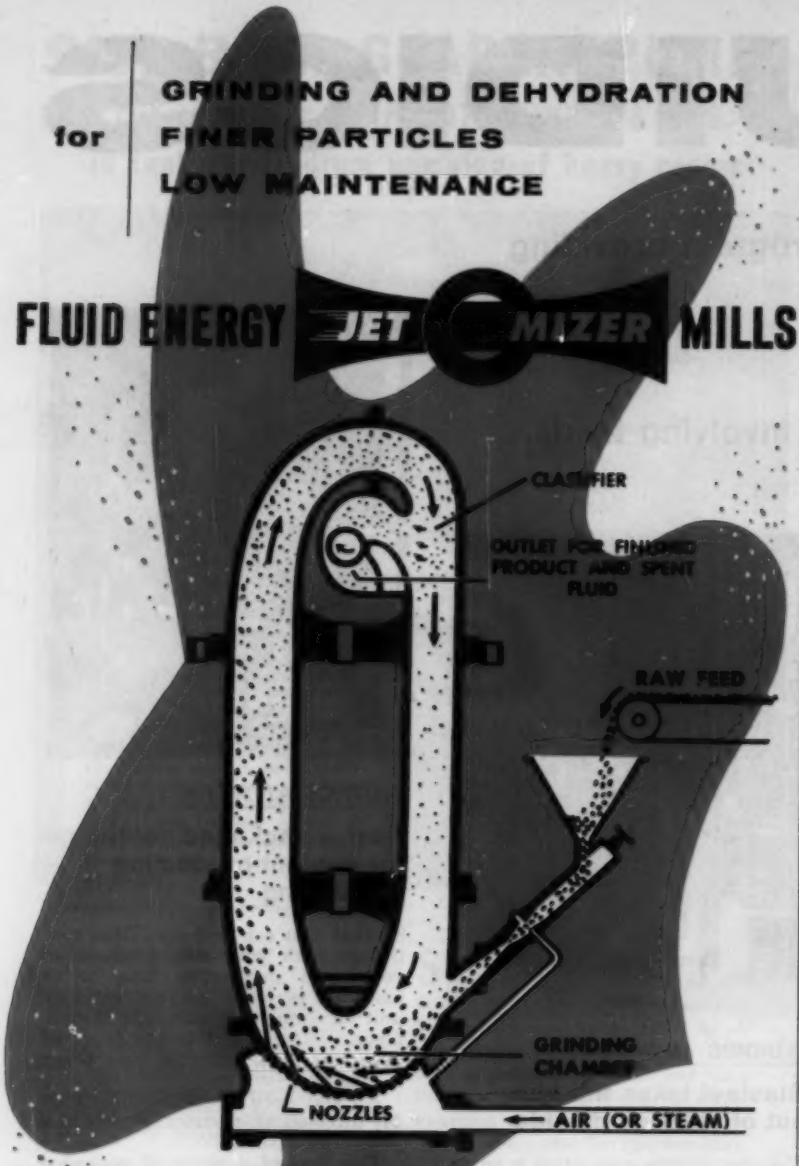
An outstanding feature of these centrifuges is their ability to desludge themselves automatically. In normal operation you can run them continuously for weeks without a major shutdown for cleaning.

For more information on the leasing program, see your local Pfaudler Permutit representative. Write for bulletin on the centrifuges to our Pfaudler Division, Dept. CEP-39, Rochester 3, N.Y.

For more information, turn to Data Service card, circle No. 62

for GRINDING AND DEHYDRATION
FINER PARTICLES
LOW MAINTENANCE

FLUID ENERGY JET-O-MIZER MILLS



The Fluid Energy "Jet-O-Mizer" Mill, designed and built by the pioneers in fluid energy fine grinding, does far more than produce fine particles. It controls fineness and product quality with a narrow distribution range and simultaneously with grinding can dehydrate, coat particles, blend and achieve chemical changes.

Jet-O-Mizer Mills are being used all over the world, processing many types of materials in the following industries:

• Abrasive	• Food	• Pigment	• Wax
• Insecticide	• Mineral	• Plastic	• Metal
• Ceramic	• Pharmaceutical	• Carbon	• Chemical

"Jet-O-Mizing" produces FINE PARTICLES ¼ micron average and above PLUS . . . Narrow Particle Distribution • Dry, or Controlled Moisture Content • Continuous Operation • Uniformity of End Product • Other Operations with Grinding • No Attritional Heat — No Moving Parts • Low Operating Costs • Low Maintenance

Send for complete information on Fluid Energy's "Jet-O-Mizer" Mills, "Jet-O-Clone" Dust Collectors, and TESTING AND CUSTOM GRINDING services.

FLUID ENERGY PROCESSING & EQUIPMENT COMPANY
Richmond & Norris Streets, Philadelphia 25, Pa. • Phone: Regent 9-7728
(Formerly known as the Wheeler-Stephanoff Mill)

For more information, turn to Data Service card, circle No. 28

industrial news

An agreement has been signed by Central Farmers Fertilizers, Midwest and Pacific Northwest agricultural cooperative, and National Potash, Carlsbad, N.M., calling for acquisition by Central Farmers of a stock interest in National, and production by National of potash materials for distribution by Central Farmers.

Research on application of the electron beam furnace to melting, refining, and casting of special metals will be pushed by Stauffer-Temescal Co., Richmond, Calif. Stauffer has just purchased the third interest in the venture previously owned by Mallory-Sharon Metals which, according to the present agreement, has been licensed to continue operation of one of the furnaces already installed at one of its facilities. The furnace uses electron bombardment in a high vacuum to melt chemically active materials with high melting points. The end product metals are claimed to be extraordinarily pure and to have "unique" physical properties. It is said to have been used successfully for melting, refining, and casting of titanium, zirconium, tungsten, molybdenum, beryllium, and columbium.

Successful application of chemical methods to make possible a tunnel-driving project in an iron ore mine is described in an Information Circular (7846) issued by the Bureau of Mines. The process used, the Joosten process, was developed in Holland and Germany, is controlled in the U.S. by the Chemical Soil Solidification Co., New York and Chicago. The method aims at chemical solidification of loose sands and soils that are permeable to water. In general, the procedure consists in the consecutive injection of two solutions, a highly concentrated solution of sodium silicate and a strong saline solution, result is precipitation of silica gel and cementation of loose sand particles.

All storage tanks for Norway's largest refinery will be furnished by Graver Tank & Mfg. Co. The 62 tanks include 4 spheres, 33 fixed-roof tanks, and 5 floating-roof tanks.

First overseas sales of 10-million volt tandem particle accelerators have been made by High Voltage Engineering Corp. One machine will go to the Swiss Federal Institute of Technology at Zurich, the second to the Australian National University.

LAPP ALL-SERVICE ACID PROOF VALVES

SOLID CHEMICAL PORCELAIN WITH **LAPP TUFCLAD.** ARMOR

Nothing defies corrosion like chemically inert porcelain. As made by Lapp, it is pure, dense, hard, close-grained, homogeneous and non-porous. Therefore there can be *no penetration—no crumbling* from capillary pressures—*no absorption* of liquids to contaminate later processing.

Resistance to corrosion and contamination is but part of the Lapp story; there's a *bonus* in that Lapp Chemical Porcelain costs considerably less initially than most corrosion-resistant alloys and lined equipment. *And* since it almost never needs maintenance or replacement, the economy of your purchase is further increased.

Security (protection of plant and personnel) is assured by the Lapp TUFCLAD armor. It consists of multiple layers of fiberglass impregnated and bonded to the porcelain with an Epoxy resin. Fiberglass has high strength and chemical resistance providing protection against impact damage and external thermal shock. TUFCLAD armor holds line pressures even should porcelain become cracked or broken.

***WRITE** for description and specifications for the entire line of Lapp Acid Proof Valves. Lapp Insulator Co., Inc., Process Equipment Div., 2304 Chestnut Street, LeRoy, N. Y.*

Lapp
CHEMICAL PORCELAIN

Y-Valves as shown, and Angle Valves are available in Lapp TUFCLAD Chemical Porcelain in ½" to 6" sizes. Also safety valves, flush valves, plug cocks, pipe and fittings (to 8" dia.) and special shapes.

For more information, turn to Data Service card, circle No. 47

Where is the money coming from?

C. R. WHITTLESEY, *Univ. of Pennsylvania*

"Finance is not a problem." That statement is a quotation from Sir Geoffrey Crowther, a distinguished British publicist, long editor of *The Economist* of London, who expressed it in connection with the financing of the Second World War. In enumerating seven things chiefly needed for war, including manpower, raw materials, and industrial capacity, money was placed last on the list. What was true of wartime economics applies as well to peacetime. Sir Geoffrey went on to say of war, as I shall say of peace, that financing is nevertheless a very important matter. But its importance lies elsewhere than is likely to be supposed at first glance.

Any ratio of investment to national income which society wants badly enough to insist upon having, can and will be financed. Saving may, of course, be less than the amount that would be sufficient to finance some announced goal of capital expansion. But all that would prove is that society as a whole wanted more leisure and more consumption more urgently than it wanted the higher figure of net investment.

Alternative methods

The primary significance of the question of financing lies in the different results that flow from alternative methods of financing. Expansion of the money supply, taxation, voluntary saving out of current income—this list is sufficient to suggest the differences that may result from financing by one means or another. It would make a difference, also, whether monetary expansion occured through the printing of greenbacks or the creation of deposits by commercial banks, with or without a corresponding expansion at the Federal Reserve Banks. There would be differences according to whether the voluntary saving of individuals and corporations was channeled through life insurance companies, savings and loan associations, savings banks, mutual funds, or otherwise.

We are better organized for financing economic development abroad than any country has ever been. Among the important financial institutions which did not exist a quarter of a century ago are the Export-Import Bank, the International Bank for Reconstruction and Development (the World Bank), and the recently-established International Finance Corporation. In addition, there is the foreign aid program of the Federal government whose activities in this area are the largest of all.

The means

The critical problem with respect to future financing is the means by which financing is to be accomplished. The answers given to this problem will determine the relative growth of particular types of enterprise such as insurance companies, and savings and loan associations. Also involved in them is the scale of participation to be exercised by Government in future economic development. The choice made with respect to the methods, and the rates, of future capital expansion will govern whether or not we are to be subjected to the perils of inflation, punctuated at times by the ravages of massive deflation.

Choice of methods is involved, in that certain means of financing, such as bank credit and consumer credit, lend themselves to easy over-expansion and subsequent contraction. Other methods, of which savings intermediaries such as life insurance companies and other thrift institutions are prime examples, are likely to exhibit a more even and orderly rate of growth. The problem that confronts the stabilization authorities is how to utilize the varying attributes of the different methods of finance so that they will serve the economy well rather than badly.

The primary criteria of economic policy are now generally considered to consist of price stability, full employment, and maximum sustainable growth. It has become commonplace to speak of these objectives in terms of the possible conflict of one with another, as though pursuit of the full employment aim condemns us to inflation, or pursuit of price stability means that we must accept continuing large-scale unemployment. This is the wrong emphasis, even though, admittedly, a three-pronged objective (price stability, full employment, and growth) is more complicated than a single objective.

There will be times when we may have to give ground on one objective in order to maintain our position on another. But we must not overlook the extent to which one objective, far from impeding, can be expected to reinforce another. At a particular moment of time, these aims may seem to be in conflict. Over the years, they are likely to prove indivisible.

The pursuit of these goals is intimately related to the financing of economic activity including capital expansion. Upon the answer that is given to the question of where, in the sense of the particular channnels, the money is coming from—and how fast—largely depends the success we shall have in achieving maximum growth combined with the nearest feasible approach to stability of prices and economic activity.

The major practical issue in connection with financing future capital requirements is one of public policy—and I would remind you that policy may be as masterly when it does nothing as when it intervenes in a positive manner. We are likely to think of the task of providing financial leadership as becoming ever more difficult. It is true that our economy grows larger and more complex with every day that passes. More is attempted and at the same time more is expected, including social and economic progress at home, and defense and development throughout the world. At the same time, economic rigidities have increased in the form of long-term wage contracts, administered prices, price supports, and interest rates that have become a doubtful automatic regulator of economic and financial behavior.

On the other hand, the problem of economic stabilization has become simpler in significant respects; if I am not greatly mistaken, it has become simpler on balance. We have banks that do not fail. We have a money supply that tends of its own accord to be notably more stable than in the past. The financial structure has been strengthened by the SEC, the FDIC, and by the healthy growth of life insurance companies and other financial intermediaries. The economy as a

continued on page 116

GIRDLER G-33 CATALYST

...proves highly active and physically rugged in hydrogenation of aromatics and other organic compounds

What it is. Girdler G-33 Catalyst contains approximately 36 weight percent nickel on a refractory oxide support. It is active for the hydrogenation of organic compounds such as aromatics, acetaldehyde and methyl-ethyl ketone in fixed bed operations...and as a methanation and deoxygenation catalyst. Can be used where catalyst bed is subjected to severe physical stress.

It is normally supplied in oxidized form as ¼" x ¼" solid cylindrical tablets of 65 lbs./cu. ft. bulk density. Minimum side crush strength is 40 lbs. dead weight load. Also available in reduced and stabilized form, designated as G-52.

How it performs. G-33 has excellent activity over a wide range of temperatures and pressures. Like all nickel catalysts, activity is reduced by only a few parts per million sulphur present in feed gas stream. It will operate successfully with sulphur compounds present. Under proper operating conditions, life of 1 to 2 years may be expected.

Applications...

- In large-scale hydrogenation of low-molecular-weight aldehydes and ketones in liquid and vapor phase.
- In hydrogenation of aromatic streams to produce pure cyclohexane...single and mixed phases in isothermal and adiabatic reactors.
- In production of cyclohexane with a purity of 99.5% (volume) from benzene.
- In removal of aromatics from naphtha feed stocks. Hydrogenates about 19% aromatics in feed stock containing 10 parts per million sulphur.

Find out how G-33 and other Girdler Catalysts, plus our complete Technical Service, can help solve *your* processing problems.

GIRDLER CATALYSTS

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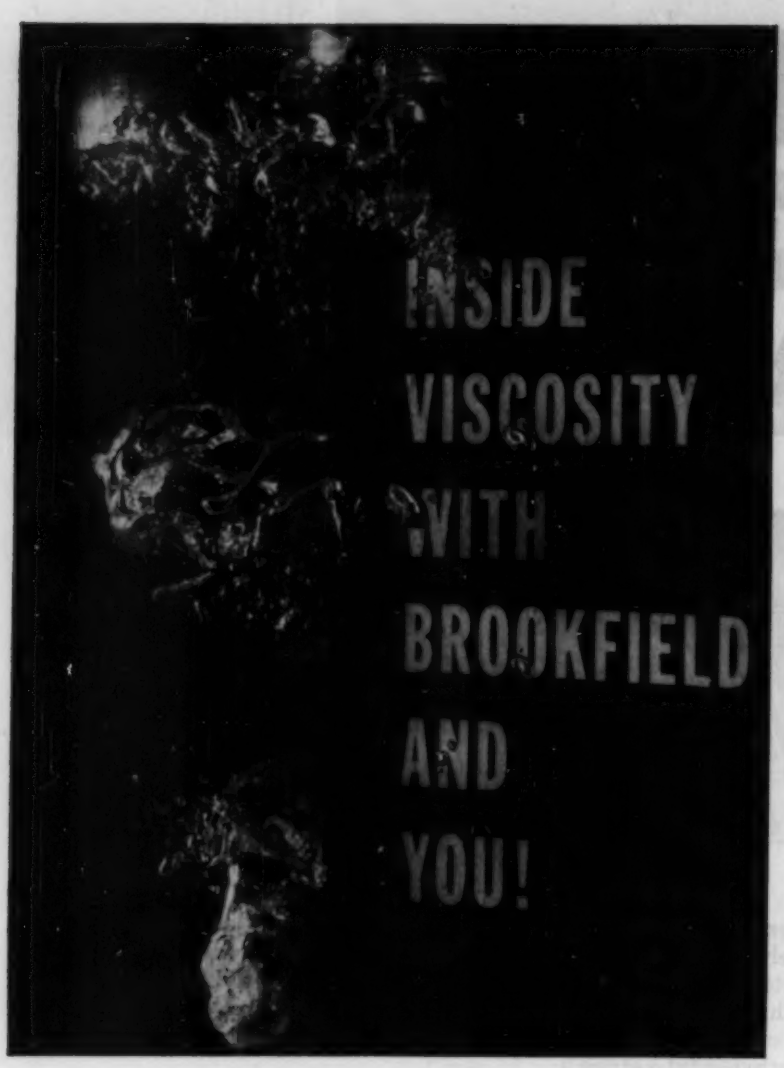
CHEMICAL PRODUCTS DIVISION • CHEMETRON CORPORATION

CHEMETRON

CATALYSTS FOR:
HYDROGENATION
SYNTHESIS GASES AND HYDROGEN GENERATION
DESULFURIZATION
NEW CATALYTIC PROCESSES

For more information, turn to Data Service card, circle No. 37



Right to the heart of this vital product dimension . . . that's where Brookfield can take you. Consider this an invitation to ask Brookfield to bring you up to date on how viscosity control, through Brookfield instrumentation, can be profitably applied to your processes. Viscosity measurement, recording and control can now be accomplished automatically for practically any fluid material. Low investment Brookfield portable and process-mounted instrumentation now plays a major role in practically every phase of chemical processing and research.

If Brookfield's long experience and coveted rheological know-how can be valuable to you, in-depth information is yours by writing—

THE WORLD'S STANDARD FOR VISCOSITY MEASUREMENT AND CONTROL

Brookfield

ENGINEERING LABORATORIES, INCORPORATED

STOUGHTON 18, MASSACHUSETTS

For more information, turn to Data Service card, circle No. 11

Money from?

continued from page 114

whole is strongly buttressed by governmental and other underpinnings, including social security, a large volume of liquid assets, improved corporate capital structures, and several highly significant automatic stabilizers. The economy has achieved these benefits while losing none of its vigor and vitality.

Not least important, we are better equipped than ever before to administer economic and financial policies wisely and well. Coordination between Treasury and the Federal Reserve central bank has been improved. The scope and magnitude of their powers, particularly when applied in conjunction, are vastly greater than in the past. Statistical and other information is far better in terms of both timeliness and coverage. And perhaps most important of all, we have reason to believe that our knowledge and understanding of economic processes, as a result of advances in the past quarter century, are better than ever before.

In short, the framework of economic theory is today, I believe, an adequate touchstone for future monetary and fiscal policy. Granted the avoidance of a major war, we can look forward to a quarter century more stable and favored than the ones we have had. Advance will continue, and, not least importantly, in the area of public policy. For this coming quarter century of progress, finance will impose problems but not obstacles.

Condensed from a talk delivered at the Golden Jubilee A.I.Ch.E. Meeting in Philadelphia.

Production capacity for tolylene diisocyanate will be expanded 50% at Mobay Chemical Co. Continued demand for polyether foams for cushioning and filling applications by automotive and furniture industries was behind this second major expansion since 1956 of Mobay's New Martinsville, West Virginia, plant. TDI facilities there will now reach 18 million pounds a year.

Annual production of anthraquinone at American Cyanamid is expected to double when a multi-million dollar addition to the firm's Bound Brook, N. J., plant is completed. Work on the new facility, which will also provide the first commercial production of naphthoquinone, is already in progress.

a IS FOR "ADAPTIONEERING"® a unique creative engineering approach which translates the knowledge gained in one field to the solution of problems in another. The A and B sections of a dictionary of products processed in S-W unit machines are available on request.

(selected from the forthcoming adaptioneering dictionary)

b IS FOR:

BAGASSE Dry and hydrolyzed bagasse has been reduced in S-W Hammer Mills and defiberized in S-W Single Runner Attrition Mills. Pith fines, both with and without molasses, are pelleted in S-W Pellet Mills.

BARK Wet spruce and hemlock bark offal reduced to 4-mesh and finer in S-W Cutters and Crushers. Other barks pelleted in S-W Pellet Mills and refined in S-W 36-2 Refiners.

BAUXITE Fines are mixed with 32% caustic in S-W Horizontal Mixers before pelleting with wood flour in S-W Pellet Mills. Lumps are reduced to a powder fine enough to pass 60-mesh and be retained on 100-mesh in S-W Single Runner Attrition Mills. Sifters and S-W Roller Mills have also been used in processing this product.

BISPHENOL "A" Leading chemical companies use S-W pneumatic systems for unloading bisphenol flakes from railroad cars. Installations usually include transfer systems to take material from storage to inplant use.

BOTTLES Soft drink bottles and medicinal bottles are reduced in S-W Single Roll Crushers. This is desired where the beverage bottles are chipped or otherwise damaged; and where bottles used for blood, pharmaceuticals or medicines must be destroyed.

BREWERS' FLAKES Product consisting of flaked, untoasted, degerminated corn reduced in Sprout-Waldron Rotary Knife Cutters. Dried spent brewers' grains are ground in S-W Hammer Mills, Single and Double Runner Attrition Mills. S-W pneumatic systems load, unload, and convey the product.

BULK TRUCK Sprout-Waldron pioneered in the development of bulk handling units, with built-in pneumatic systems which make it possible to load and unload dry, granular materials without back breaking labor, contamination, dusting or waste. Sprout-Waldron bulk trucks have handled materials ranging from peanut shells to cement spanning densifications from 10 to 95 lbs./cu. ft. Chassis sizes range from 12 to 36 feet.

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Manufacturing Engineers

MUNCY, PENNSYLVANIA, U. S. A.

SINCE 1866 Size Reduction • Size Classification • Mixing and Blending • Bulk Materials Handling • Pelleting

CW/102

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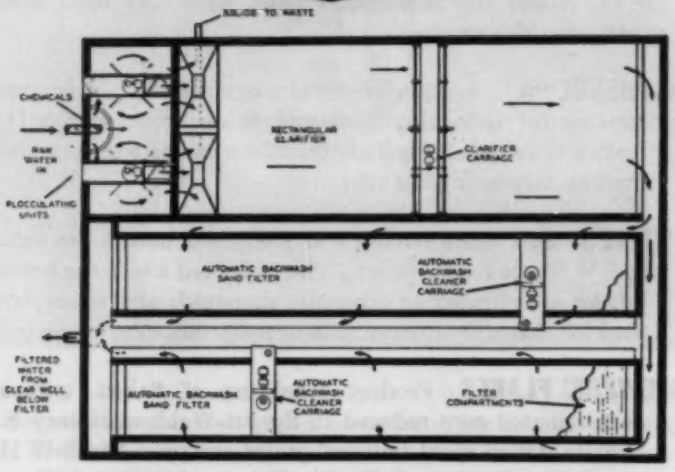

...for COMPLETE WATER TREATMENT in Modular Construction

A real "thirst quencher" for industrial and municipal water supplies is the Hardinge equipped water treatment plant—available in unit sizes of from 1 M.G.D. to 5 M.G.D.

Can be furnished complete with automatic plant controls.

Write for full details.

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For more information, turn to Data Service card, circle No. 38

industrial news

Production of styrene gets underway near Melbourne, Australia, shortly, when construction starts on a styrene monomer plant by CSR-Dow Pty., Ltd. The new company, jointly owned by Dow Chemical and C.S.R. Chemicals Pty. Ltd., plans to complete the four-unit petrochemical complex by mid-1961.

Sodium and chlorine production capacity at Du Pont is expected to increase 50% with the recent completion of a new sodium and chlorine unit at the firm's Memphis plant.

Synthetic Camphor will no longer be produced by Du Pont. Material for production of medicinal and technical grade synthetic camphor, including patents, formulas and processes, has been purchased by Chas. L. Huisking & Co., New York City. Huisking has also purchased Du Pont's current stock of camphor.

Production capacity of high pressure polyethylene at Monsato Chemical will be increased to 100 million pounds a year. Facilities are scheduled for completion late this year.

Solid 20.5% lime nitrate and a full line of nitrogen solutions will be manufactured by Florida Nitrogen's new plant near Tampa. Construction begins at once by this new subsidiary of Southern Nitrogen, which will be supplied with ammonia by the parent firm's 20-25% expanded production. Florida Nitrogen's three plant expansion plans include an ammonia, and a nitric acid plant.

A new polyethylene unit in Melbourne, Australia, with production capacity of 15 million pounds annually, is scheduled to begin operation early in 1961. It will be erected and operated by Union Carbide Australia, Ltd.

A sulfur recovery unit placed in operation recently at Sun Oil's Toledo refinery, has a capacity of 12½ long tons a day. The new unit converts hydrogen sulfide to sulfur dioxide, and in the presence of a bauxite catalyst, to elemental sulfur.

The American Society of Heating Refrigeration and Air-Conditioning Engineers has been formed by a merger of ASHACE with ASRE. Cecil Boling is president of the 18,000 member organization.

For more information, circle No. 20

NOW... EVEN LARGER DENVER TURBINE PROPELLER AGITATORS

For Effective Propeller Agitation in Tanks as Large as 50′ Diameter

Design of DENVER turbine type propeller makes possible large diameter propeller agitators for agitating large volumes of pulp in large tanks. One large diameter agitator handles volume of several small ones—saves space, operating expense, supervision, maintenance.

- Large diameter propeller operating at low speeds gives proper agitation with heavy slurries even as coarse as 10 mesh. Slower speeds mean savings in horsepower and further savings from reduced wear.
- Propeller is designed for long service. High mechanical efficiency moves pulp with minimum of turbulence—blades wear evenly and uniformly with no cavitation.
- Large diameter DENVER turbine type propeller eliminates problems often encountered with airlift or rake agitators—cuts need for operating attention, saves on maintenance.

Find out how large diameter DENVER Turbine Propeller Agitators can save you money—build your profits. Send details of your requirements for careful, detailed recommendation on the correct agitator for your operation.

Leading Suppliers of Agitators for:

AGITATION
SCRUBBING
MINE BACKFILL AGITATION
PRECIPITATION
REPULPING
SLURRY HOLDING
MIXING
CONDITIONING
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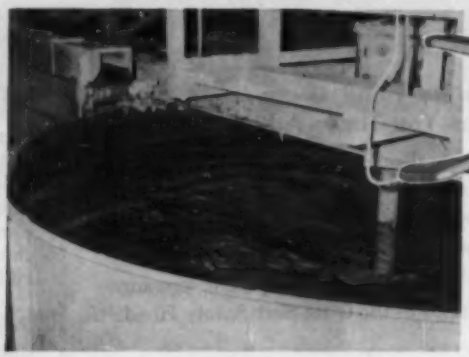
SOLVENT EXTRACTION

WRITE FOR BULLETIN NO. A2-B6



96" diameter DENVER Propeller Agitator on Test Rack at DENVER Factory, to be used in 20′ diameter by 23′ deep tank.

"The firm that makes its friends happier, healthier and wealthier"

DENVER EQUIPMENT COMPANY

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- JOHANNESBURG
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DECO

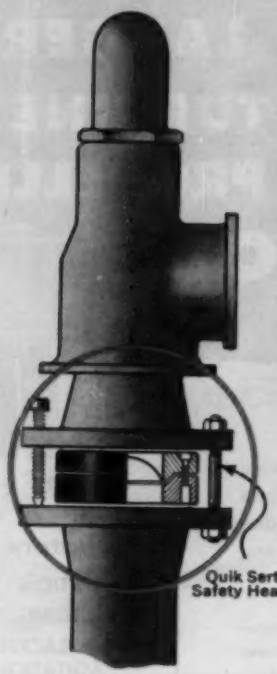
DENVER EQUIPMENT 24 HOUR SERVICE COMPANY

Complete Mill Equipment

You Can Prevent These Three Relief Valve Problems With a BS&B Quik-Sert *Safety Head!*

BEFORE

AFTER



Leakage
Corrosion
"Freeze-ups"

The BS&B Quik-Sert Safety Head isolates the relief valve from the product under pressure. Mounted under the valve inlet, it is "bottle tight" until overpressure reaches the rated pressure of the preformed metal rupture disc.

The Quik-Sert Safety Head flange assembly is located inside the bolting of companion flanges. Easy insertion and removal is accomplished through the use of jack screws.

A BS&B Quik-Sert Safety Head Under the Relief Valve Gives You These Advantages

- Stops product loss at normal operating pressures
- Assures proper valve function at set pressure
- Lowers maintenance costs
- Reduces shutdown time

BS&B engineers will be glad to evaluate your pressure system for proper applications of the Quik-Sert Safety Head.

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For more information, turn to Data Service card, circle No. 8

industrial news

Rhenium will now be produced commercially, in the Research and Development Department of Chase Brass & Copper. Consumption of wrought rhenium, which has a tensile strength of 350 thousand lb./sq. in., and melting point of 5756° F, has increased over 400% in the past years.

A new ¾ million dollar pilot plant is planned for Carborundum's Research and Development Division in Niagara Falls, N.Y. Special equipment for products requiring ultra-high temperature processing techniques will be provided by the plant, scheduled for completion in one year.

A uranium processing mill in the Gas Hills area near Riverton, Wyoming, with capacity of 522 tons a day, will be built by Federal Uranium Corp. When negotiations with the AEC on a concentrate purchase agreement are final, construction (scheduled for April 1), will begin.

A $2 million expansion in chlorine-caustic soda facilities is in progress at Diamond Alkali, Painesville, Ohio. Replacement of the Tucker-Windecker type cells with Diamond's new 30,000-ampere rectangular cells will utilize 60% less space than formerly, also reduce the number of cells required from 2,432 to 144.

30 million pounds of phthalic anhydride will be produced annually by Reichhold Chemicals' new $5 million plant in Elizabeth, N. J. Construction is expected to be finished in late 1959.

A polymer plant is planned as a further expansion of the new 55,000 barrel-a-day fluid catalytic cracking plant operation at Standard Oil of California's Richmond, Cal., refinery. This third auxiliary plant brings the company's investment in the new cracking facility to more than $30 million.

Full scale production of Trycite, Dow Chemical's polystyrene film, has begun at the Cleveland plant.

A research participation program for qualified teachers of chemical engineering, physics, and chemistry in smaller colleges will be held at Penn State University for two months starting June 8, 1959. Professor W. C. Fernelius at Penn heads arrangements.

GUIDANCE...

It was only when man recognized nature's navigational "signposts" in the skies, and learned to read them, that he gained mastery over the seas.

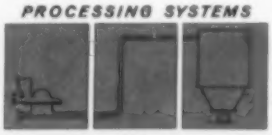
In the same way, the processing industries have welcomed guidance, and utilized every opportunity designed to help them toward more efficient and economical operation. Our contribution — in the field of grinding, air conveying and dust collection — is embodied in the Mikro Plan. The Plan includes: *Mikro Engineering, which works constantly to create equipment for new uses and to improve existing methods . . . Mikro Laboratory Analysis, aimed at more effective methods of processing customers' materials . . . and Mikro Service, organized on a world-wide basis for on-the-spot solution of problems, and the shipment of genuine MIKRO replacement parts to any point within 48 hours of order.*

Our experience and facilities are at your disposal without obligation. Call on us at any time.

MIKRO-Products

SPAN THE GLOBE

PROCESSING SYSTEMS



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MANUFACTURING FACILITIES: United States, Canada, Continental Europe, British Isles.

the X-15

The 1-mile-per-second X-15, designed to carry its pilot into the fringes of space, is a product of joint efforts of NASA, Air Force and Navy, with close cooperation of North American Aviation, Reaction Motors and 300 other contracting firms. This aircraft —latest in a long-term program conceived by NASA scientists for the advanced study of the problems of flight—will make its first flights soon. NASA has technical direction of the X-15 project and will report the research results for use by Government and industry.

The X-15 is a *rocket research airplane*, a flying laboratory.

Primary research interest in the X-15 is to obtain knowledge of actual flight conditions in the near space environment, to produce a wealth of information from repeated missions involving entry into and exit from the atmosphere. And *only man* can prove how man will react in space to weightlessness and intense acceleration and deceleration.

The X-15 program is typical of the exciting things happening at NASA, whose responsibility it is to direct and implement U. S. research efforts in aeronautics and the exploration of space, for peaceful purposes and the benefit of all mankind.

NASA offers unique opportunities in basic and applied research in aeronautics and space technology—

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Aeronautical, Engineering Physics, Electronic, Mechanical, Electrical, Metallurgical, Chemical, Civil.

For Scientists:
Astronomers, Physicists, Mathematicians, Chemists, Metallurgists.

Please address your inquiry to the Personnel Director of any of the following NASA research centers:

- **Langley Research Center, Hampton, Virginia**
- **Ames Research Center, Mountain View, California**
- **Lewis Research Center, Cleveland, Ohio**
- **High-Speed Flight Station, Edwards, California**
- **Beltsville Space Center 4555 Overlook Ave., Washington, D.C.**

(Positions are filled in accordance with Aeronautical Research Announcement 618)

NASA National Aeronautics and Space Administration

Louisville Dryer—10 feet in diameter, 10 stories long!

Turn a ten story building on its side, and there'd be room to spare on either end of this huge pit lathe at Sharon, Pennsylvania where this 10′ x 110′ Louisville Dryer was fabricated.

This lathe is used for machining the reinforcing bands onto which are mounted the forged steel tires. This careful workmanship assures concentricity of the completed dryer shell—a primary factor in efficient seal operation.

Every Louisville Dryer is especially designed, manufactured, assembled and installed for its specific task.

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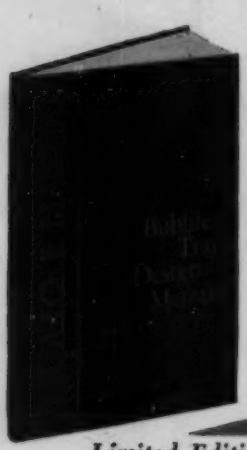
In Canada: Canadian Locomotive Co., Ltd., Kingston, Ontario

For more information, turn to Data Service card, circle No. 29

Results... *from a five-year study of bubble-tray efficiencies*



An A.I.Ch.E. Technical Manual

Bubble-Tray Design Manual

prediction of fractionation efficiency

by the
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1. Enables the engineer to predict efficiencies for commercial bubble trays used in multicomponent fractionation.
2. Contains sample calculations made on plant-scale columns.
3. Includes calculation form sheets for the use of the reader. (Additional sheets may be purchased.)

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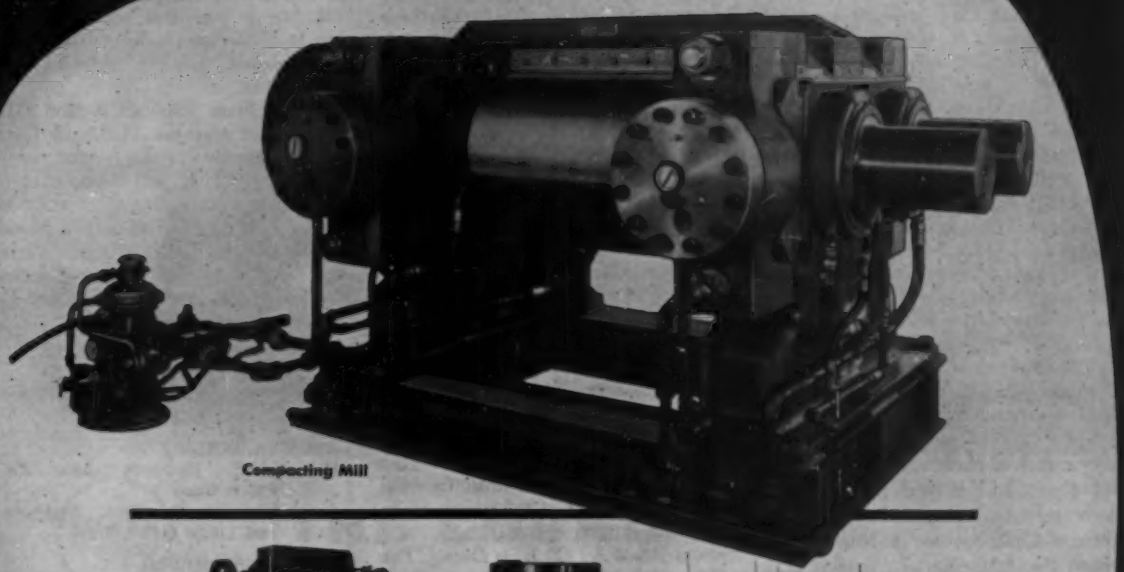
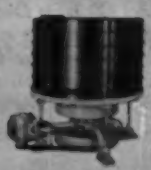


Compacting Mill

Roller-type Granulating Mill



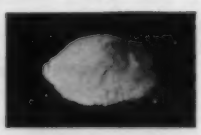
Gyratory Screen

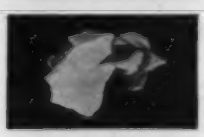
Vibrating Screen

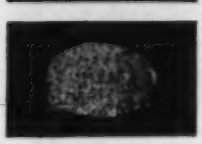
Allis-Chalmers compacting process

Rescues "Lost" Profits

...converts waste chemical fines into a salable product







A potash producer salvages seven tons per hour from sub-sized fines. A chemical salt manufacturer effects an 80% recovery of marketable material. Yes, waste becomes valuable when put through the Allis-Chalmers compacting process.

The compacting system is a package of integrated Allis-Chalmers equipment — the remarkable new compacting mill, a roller mill and either a gyratory or vibrating screen. The compacting mill mechanically densifies fines created in your original process. The resulting flakes or slabs are granulated in the roller mill and separated in the screen. Precise control of particle size, density and solubility factors is assured. Recovered product equals or surpasses parent product in every respect.

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Kansas City—Technical Program

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The Kansas City Meeting in May will inaugurate a series of several petroleum production symposia to be presented at A.I.Ch.E. meetings under the joint sponsorship of A.I.Ch.E. and the Society of Petroleum Engineers of AIME. These symposia will deal exclusively with the fundamental chemical engineering principles which are considered basic to the understanding and successful operation of petroleum production processes—in particular, with the phenomena associated with the withdrawal of gas and oil from deep-lying reservoirs. It is expected that these symposia will stimulate a greater interest on the part of the chemical engineering profession in these fascinating and challenging mile-under-the-earth fluid mechanics techniques. In this field, there will be three sessions: one, led by M. J. Rzasa of Cities Service on *Non- Equilibrium Fluid Mechanics* (Session 11); the second and third on *The Role of Wetting and Capillarity in Fluid Displacement Processes* (Sessions 13 & 15), under C. S. Kuhn of Magnolia Petroleum. For full details of these unusual symposia, see the meeting program below.

The Engineering Profession and the American Institute of Chemical Engineers will be the subject of a Panel discussion on Sunday afternoon, May 17. L. K. Wheelock, executive secretary of the Engineering Manpower Commission will lead off the session with a talk on *Salary Survey by Engineering Manpower Commission, Pay for Engineers, 1958, and Supply and Demand for Engineers. Utilization of Engineers* will be analyzed by T. J. Mills, program director for Scientific Manpower, Wash., D. C. A. H. Goeser, director of human relations, World Insurance Co., Omaha, Neb., will speak on *It's Human Relations that Count.* To wind up the formal part of the panel, D. L. Katz, president of A.I.Ch.E., will discuss *What A.I.Ch.E. is Doing.* The talks will be brief, leaving plenty of time for discussion from the floor.

The schedule of plant tours for the Kansas City Meeting is now complete—a convenient summary is given in the box accompanying this story. As attendance on these trips is necessarily limited, preregistration is urged. All trips can be completed within one-half day or less—this was made the rule to allow maximum flexibility in the personal meeting schedules of participants.

The William Rockhill Nelson Gallery of Art and the Hallmark Card Building are two of the central points of interest which will form part of the Ladies Program. Also sure to be popular with the ladies will be a visit to the famous Country Club Plaza, where a fashionable shopping center has been built in the style of the old Spanish missions.

Plant Trip Schedule

Monday Morning

M-1 SAGE, Richards-Gebaur Air Force Base
M-2 Midwest Research Institute and Linda Hall Library

Monday Afternoon

M-3 Buick-Oldsmobile-Pontiac Assembly Division
M-4 Cook Paint & Varnish Co.
M-5 Phillips Petroleum Co.

Tuesday Morning

T-6 Spencer Chemical Co. Research Center and Delco-Remy Division
T-7 Corn Products Co.
T-8 Fairbanks-Morse & Co.

Tuesday Afternoon

T-9 Sheffield Div., Armco Steel Corp.
T-10 Procter & Gamble Mfg. Co.
T-11 Jos. Schlitz Brewing Co.

Wednesday Morning

W-12 Standard Oil Co.
W-13 Owens-Corning Fiberglas Corp.

Three-Day Schedule of Technical Sessions

MONDAY, MAY 18

9:00 to 11:30 A.M.
TECHNICAL SESSION NO. 1—COMPUTERS AND PIPELINES.

Chairman: R. L. McIntire, Datics Corp.

Design and Analysis of Natural Gas Gathering Systems by Digital Computation, B. L. Giles, Phillips Petroleum. A novel method of network analysis is used to design and analyze natural gas gathering systems on the IBM 709 digital computer.

Evaluation and Design of Pipeline Networks, R. J. Hunn, Du Pont, R. L. McIntire and K. L. Austin, Datics Corp. Three-dimensional looped pipeline systems, with pumps, strainers, and orifices considered as integral members of the system, designed on commercially available digital computing equipment.

The Electronic Computer as Applied to Gas Pipeline Design, H. B. Martch, Jr., El Paso Natural Gas Co. Digital computer appliction to computation of pipeline flow losses, compressor horsepower, and loop lengths.

Digital Computer Solution of Gas Distribution Network Flow Problems, D. V. Kniebes & G. G. Wilson, Inst. of Gas Technology, Chicago. Digital computer solution of gas distribution system network flow problems using the Hardy Cross method.

9:00 A.M. to 12 Noon
TECHNICAL SESSION NO. 2—THERMODYNAMICS OF JET AND ROCKET PROPULSION.

Chairman: G. C. Szego, Space Technology Laboratory.

Thermodynamics and Missile Performance, H. C. Rodean, Chance Vought Aircraft. A concise analysis of the dependence of rocket missile performance upon several thermodynamic parameters.

One Dimensional Flow with Chemical Reaction in Nozzle Expansion, T. W. Reynolds & L. V. Baldwin, NASA Lewis Research Center. The complex interactions when chemical reactions take place during the expansion of hot gases in rocket nozzles.

Dissociation Non-Equilibrium in Hypersonic Nozzle Flow, J. G. Hall, Cornell Aeronautical Lab. Chemical kinetics with reference to their role in hypersonic nozzle flow.

Aerothermochemistry, Scaling, and Instability of Liquid Propellant Rocket Motors, T. P. Torda, Brooklyn Poly. Factors and problems encountered in design and operation of liquid propellant rocket engines, with particular reference to combustion instability.

The Need for Rocket Engines of Higher Thrust per Nozzle Area in High-Speed Sled Testing, P. P. Kuhn, Holloman Air Force Base. Thermodynamic background for design of rocket engines for high-speed sled testing.

Thermodynamic Properties of Some Gaseous Metal Compounds, A. Buechler, Arthur D. Little. New and unpublished thermodynamic properties of advanced rocket propellants.

continued on page 128

The Inquiring Mind at Oldsmobile

no. 8 OF A SERIES

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The quiet, solid feeling inside the 1959 Oldsmobile results from patient testing by a highly specialized "jury"—experts in the field of sound analysis.

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For the greatest possible accuracy, considerable care is taken making the recordings. Special microphones are placed at points corresponding to the passengers' ears. The recording equipment is in a specially equipped vehicle which follows the test car over a "ride road" that is carefully constructed to excite the vibrations and sounds that occur under normal driving conditions.

Quality, like quietness, is not accidental. It is the deliberate effort by Oldsmobile engineers to *design* quality into every automobile they produce. You'll like the 1959 Oldsmobile—with its solid Body by Fisher—it's the quietest car built! Experience this quality for yourself by visiting your local Authorized Oldsmobile Quality Dealer as soon as possible.

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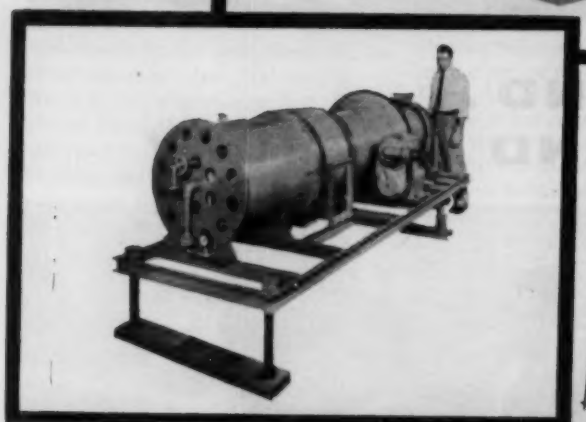

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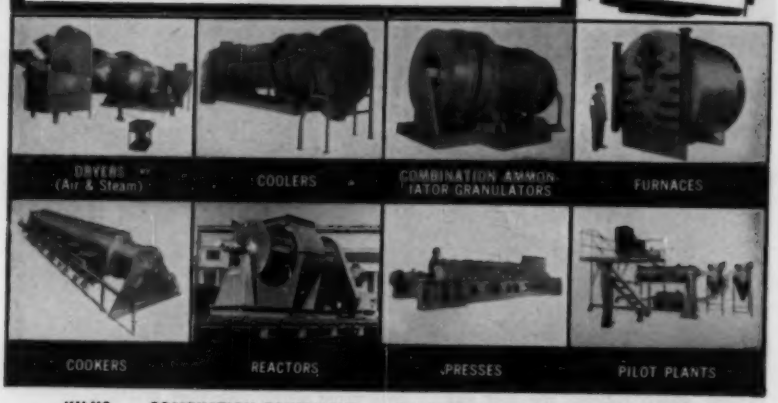

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For more information, turn to Data Service card, circle No. 70

Kansas City

from page 126

9:00 to 11:30 A.M.
TECHNICAL SESSION NO. 3—INTERNATIONAL LICENSING AND COLLABORATION.

Chairman: Ralph Landau, Scientific Design.

Progress Through Process Licensing in the Petroleum Industry, W. C. Asbury, Esso Research & Engineering. Technological progress is due, at least in part, to the existance of a patent system which permits dissemination through licensing.

Problems in the International Licensing of Patents and Technology in the Chemical Industry, H. W. Knauff, Farbenfabriken Bayer (Germany). A change away from the previous stringent secrecy has taken place in the European chemical industry policy toward licensing knowhow and patents.

Legal Aspects of Foreign Licensing, T. G. Gillespie, Jr., Scientific Design. Legal paths and pitfalls to be trod and avoided in foreign licensing, including the impact of the Common Market Treaty.

Export Control of Technical Data by the United States, F. W. Sheaffer, U. S. Dept. of Commerce. Export controls over technical data are designed to permit free interchange of data between the United States and friendly countries while carefully restricting the outflow of advanced technology to the Soviet Bloc.

2:00 to 5:00 P. M.
TECHNICAL SESSION NO. 4—GENERAL SESSION.

Chairman: J. O. Maloney, Univ. of Kansas.

Methods of Handling Non-Ideal Vapor-Liquid Equilibria Calculations in Digital Computer Distillation Programs, N. G. O'Brien & R. L. Turner, Du Pont. Incorporation of information on non-ideal vapor-liquid equilibrium behavior into those distillation calculations in which a digital computer is used.

The Thermal Properties of Methyl Borate, C. E. Hansen & R. L. Hughes, Midwest Research Inst., Kansas City. Thermodynamic charts and tables on methyl borate.

The Effect of Dynamic Surface Tension on Nucleate Boiling Coefficients, P. D. Jontz & J. E. Meyers, Purdue. Effect on bubble formation characteristics of the surface tension of aqueous solutions.

Prediction of Pseudocritical Parameters for Mixtures, W. E. Stewart, S. F. Burkhardt, & David Voo, Univ. of Wisconsin. The corresponding states correlation of Lyderson, Greenhorn, and Hougen used to predict the compressibility behavior of mixtures by an extension of pseudocritical approach.

Correlating Criteria for Liquid Phase Adsorption, H. L. Jones, Jr. & E. B. Stuart, Univ. of Pittsburgh. A equation proposed by Stuart and Coull by which selective adsorption of benzene-cyclohexane on silica gel could be correlated has been altered to predict the benzene-cyclohexane data over a wider range of temperatures and pore diameters.

2:00 to 4:30 P.M.
TECHNICAL SESSION NO. 5—TEN WAYS TO IMPROVE TECHNICAL REPORTS.

Chairman: Robert Gunning.

A seminar aimed at clear writing and at organization of reports for clear, forceful communication.

2:00 to 5:00 P.M.
TECHNICAL SESSION NO. 6—GROWTH POTENTIALS OF THE HEAVY CHEMICALS INDUSTRIES IN CENTRAL U. S.

Chairman: N. J. Ehlers, Columbia-Southern Chemical.

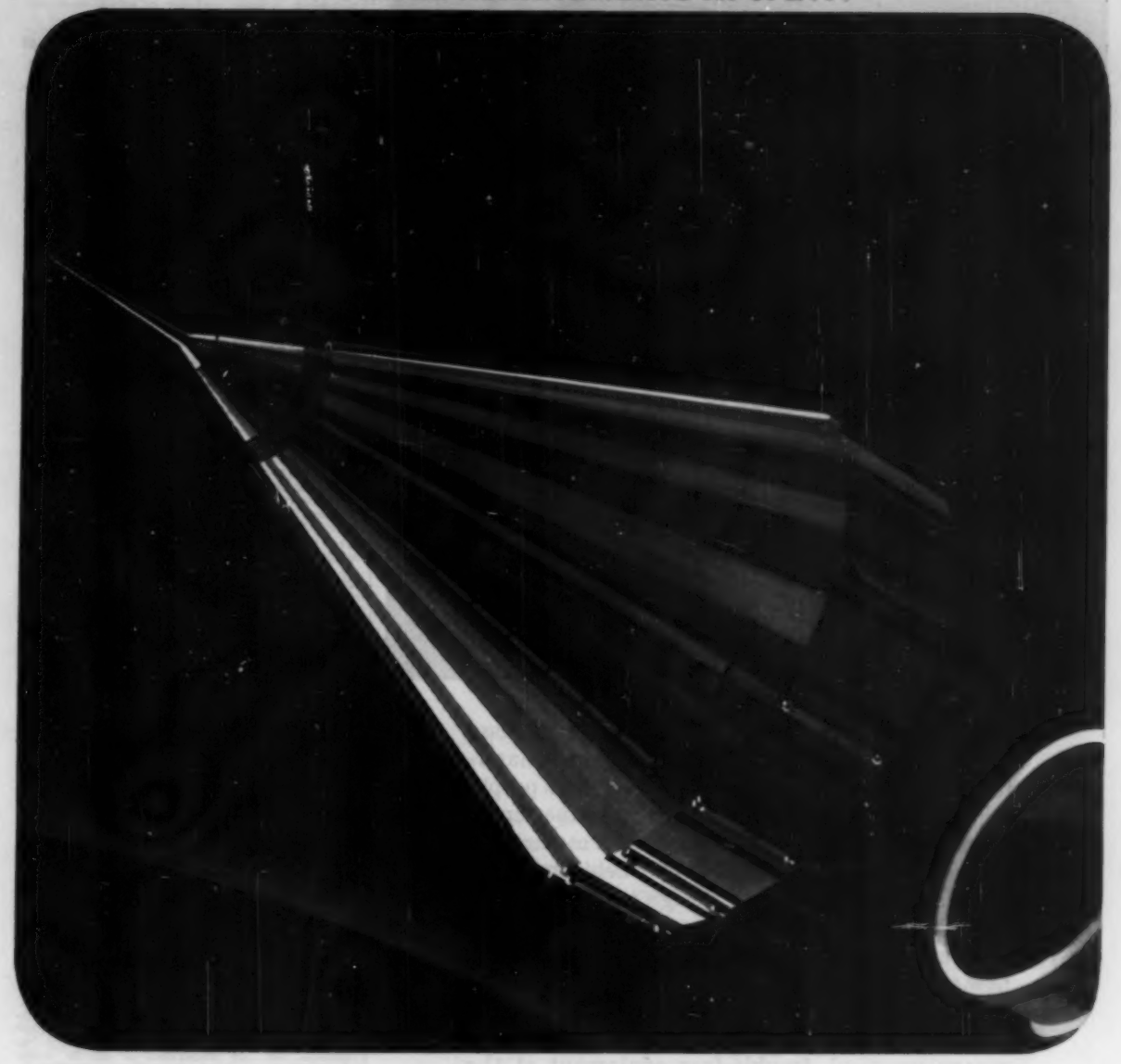
Soda Ash from Trona, H. A. Sommers. Wyoming Trona offers the possibility of meeting all future soda ash needs at capital and production costs much lower than those of the conventional ammonia-soda process.

Growth Potentials of the Nitrogen Industry in Central U. S., F. O. Agel, Allied Chemical. Present status and an assessment of future potential of the fixed nitrogen industry in central U. S.

Growth Potentials of the Sulfuric Acid Industry in Central U. S., J. H. Zwemer & C. M. Dean, Monsanto. Central U. S. daily capacity will increase to 25,000 tons by 1975 compared to 15,000 tons in 1957, while national production will increase from 16 million to 25 million tons annually by 1975.

continued on page 130

NOTABLE ACHIEVEMENTS AT JPL...



PIONEERING IN SPACE RESEARCH

Another important advance in man's knowledge of outer space was provided by Pioneer III. This, like many others of a continuing series of space probes, was designed and launched by Jet Propulsion Laboratory for the National Aeronautics and Space Administration. JPL is administered by the California Institute of Technology for NASA.

During its flight of 38 hours, Pioneer III was tracked by JPL tracking stations for 25 hours, the maximum time it was above the horizon for these stations.

The primary scientific experiment was the measurement of the radiation environment at distances far from the Earth and telemetering data of fundamental scientific value was recorded for 22 hours. Analysis of this data revealed, at 10,000 miles from the Earth, the existence of a belt of high radiation intensity greater than that observed by the Explorer satellites.

This discovery is of vital importance as it poses new problems affecting the dispatch of future vehicles into space. The study and solution of such problems compose a large part of the research and development programs now in extensive operation at the Laboratory.

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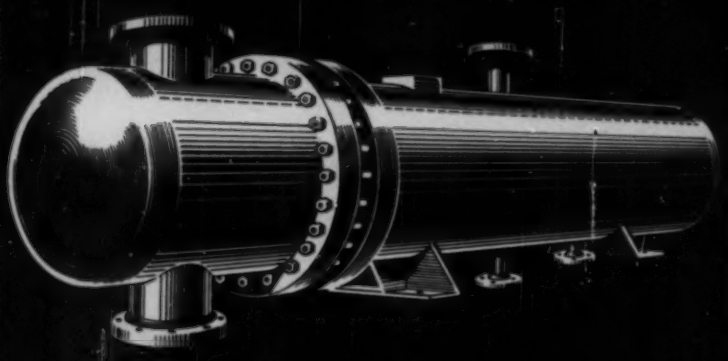

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For more information, turn to Data Service card, circle No. 52

Kansas City

from page 128

Growth Potentials of the Chlor-Alkali Industry in Central U. S., W. H. McConnell & K. S. Lewis, Diamond Alkali. Prospective national future growth and increased utilization of resources, combined with the central geographic location of the area, provide potential for an unprecedented acceleration in development.

Growth Potentials of the Petrochemical Industry in Central U. S., T. L. Cubbage, Phillips Chemical. The central U. S. area favors long-term growth of the ammonia industry and production of higher-priced specialty petrochemicals; significant growth in production of ethylene and acetylene petrochemicals is unlikely unless new methods are developed for economic production from oil and gas feed stock.

TUESDAY, MAY 19

9:00 A.M. to 12 Noon

TECHNICAL SESSION NO. 7—PETROCHEMICALS.

Chairman: G. E. Montes, U. S. Industrial Chemicals.

The Alkar Process—Flexible in Its Applications. H. Grote & C. F. Gerald, Universal Oil Products. Yields and economics of a new process for alkylation of aromatics with olefins in low or high concentrations.

The Role of a Process Engineer in a Petrochemicals Plant, D. J. Cestoni, B. H. Kramer, L. R. Olson, & R. E. Ringelman, American Cyanamid. Application of modern engineering tools for optimization of three different petrochemical processes.

Economics of Ethylene Oxide Manufacture, David Brown, Scientific Design. Compares economics and technology of three modern processes.

Acetylene and Ethylene from Pyrolysis of Natural Gas Liquids and Petroleum Distillates—Correlation of Pyrolysis Data, J. M. Reid & H. R. Linden, Inst. of Gas Technology, Chicago. A method of data correlation which permits comparison of results obtained on various different kinds of thermal cracking apparatus.

Removal of Acetylene from High Purity Ethylene by a Selective Solvent. H. C. Schutt, consultant. Use of acetone as a selective solvent for removal of acetylene from high-purity ethylene.

TECHNICAL SESSION NO. 8—GENERAL SESSION.

Chairman: Mark Hobson, Univ. of Nebraska.

Use of Momentum Balance in Calibrating Orifices for Flow of Gases, J. J. Martin & V. R. Pabbi, Univ. of Mich. How to calibrate gas flow orifices without using gas holders or other comparative devices.

Dispersions Caused by Turbulence in Pipes, R. W. Kessie, Argonne Nat. Lab., & J. H. Rushton, Purdue Univ. Effects of turbulence, pipe length, and turbulence generators such as orifices, etc. on dispersion of oil in water determined by light transmission technique.

Expansion and Contraction of an Air-Water Mixture in Vertical Flow, M. Petrick, Argonne, & B. S. Swanson, Ill. Inst. of Technology. Two-phase flow of air-water mixture shows that density of the mixture can be predicted by a semi-theoretical equation.

Boundary-Layer Behavior on Continuous Solid Surfaces: Equations for Two-Dimensional and Axisymmetric Flow, B. C. Sakiadis, Du Pont. The basic differential and momentum integral equations of boundary layer theory derived for continuous solid surfaces.

Boundary-Layer Behavior on Continuous Solid Surfaces: The Boundary Layer on a Continuous Flat Surface and on a Continuous Cylindrical Surface, B. C. Sakiadis, Du Pont. The laminar boundary-layer behavior on a moving flat surface investigated by two methods; the behavior of laminar and turbulent boundary layers on a moving cylindrical surface investigated by the integral method.

TECHNICAL SESSION NO. 9—REACTION KINETICS.

Chairman: M. M. Gilkeson, Tulane.

A Moving Bed Reactor for the Production of Uranium Tetrafluoride, D. S. Arnold, P. W. Henline, & R. H. Sisson, National Lead. Design and operating criteria for the moving bed reactor system for production of uranium tetrafluoride from uranium trioxide.

Reaction Rates in the Synthesis of Ammonia. A. K. Mills & C. O. Bennett, Purdue. Correlations using the mechanism proposed by Temkin and Pyzhev.

Kinetics of the Catalytic Vapor-Phase Oxidation of Phthalic Anhydride, M. F. Hughes & R. T. Adams, California Research. Oxidation of phthalic anhydride over a vanadia catalyst at 497-575°C.

Effect of Mass Transfer on Solid-Catalyzed Reactions: The Dehydrogenation of Cyclohexane to Benzene, L. G. Barnett, R. E. C. Weaver, & M. M. Gilkeson, Tulane. Over a portion of the range of variables, joint control of the rate by surface reaction and both internal and external mass transfer was evidenced.

2:00 to 5:00 P.M.

TECHNICAL SESSION NO. 10 — GENERAL SESSION.

Chairman: G. H. Beyer, Univ. of Missouri.

A Study of Streams of Solids Flowing from Solid-Gas Fluidized Beds, V. Betta & C. Della Rocca, Univ. of Naples (Italy). An experimental and analytical study.

The World's First Fully Integrated Polystyrene Plant, C. E. Belton, Cosden Petroleum. A description of novel features.

Recovery of Uranium in the Manufacture of Wet Process Phosphoric Acid, E. W. Nadig & O. Burnet, Jr., Iowa State College. Seventy-five to eighty percent of the uranium entering in the phosphate rock was found in a recoverable form in the product acid at two plants studied.

Fused Salt Extraction of Magnesium from a Magnesium-Bismuth Alloy, P. Josephson, E. Olson, & M. Smutz, Iowa State College. Removal of magnesium from a 3 mole % magnesium-97 mole % bismuth alloy using a 54 mole % zinc chloride-46 mole % potassium chloride fused salt.

Purification of Propylene for Polypropylene Production, W. R. Gutman, J. S. Cromeans, & H. W. Fleming, Catalysts and Chemicals, Inc. Use of several catalytic processes for removal of acetylenes, diolefins, and sulfur compounds from propylene.

TECHNICAL SESSION NO. 11—NON-EQUILIBRIUM FLUID MECHANICS.

Chairman: M. J. Rzasa, Cities Service Research and Development.

Diffusion in Compressed Binary Gaseous Systems, V. J. Berry, Jr. & R. C. Koeller, Pan American Petroleum. Experimental determination of diffusion coefficients in dense gas systems to pressures of 15,000 lb./sq. in.

The Diffusional Behavior and Viscosity of Liquid Mixtures, A. W. Adamson, Univ. of Southern Calif. A case model for transport processes in liquid mixtures applied to diffusion, thermal diffusion, sedimentation, and viscosity.

Displacement of Oil by Rich Gas Banks, C. W. Arnold, H. L. Stone, & D. L. Luffel, Humble Oil and Refining. Effects of various factors on efficiency of banks of enriched gas driven by methane in displacing oil from a porous media.

Unsteady State Liquid Flow Through Porous Media Having Elliptic Boundaries, K. H. Coats, M. R. Tek, & D. L. Katz, Univ. of Mich. Treatment of the problem by a numerical method using an IBM 704 digital computer.

TECHNICAL SESSION NO. 12 — REACTION KINETICS.

Chairman: M. M. Gilkeson, Tulane Univ.

Shock-Induced Chemical Reactions: Hydrogen-Deuterium Exchange, M. E. Gluckstein & S. W. Churchill, Univ. of Mich. The exchange reaction between hydrogen and deuterium investigated in a shock tube.

The Dual Nature of Catalytic Reactions: The Dehydrogenation of Sec-Butyl Alcohol to Methyl Ethyl Ketone at Elevated Pressures, L. H. Thaller & G. Thodos, Northwestern Univ. The controlling step involving the desorption of molecularly adsorbed hydrogen ceases to exist with changes of the operating variables in favor of a dual site surface reaction.

The Dynamics of Heat Removal from a Continuous Agitated Tank Reactor, R. J. Fanning & C. M. Sliepcevich, Univ. of Oklahoma. The dynamic characteristics of a continuous, agitated tank reactor vessel.

continued on page 132

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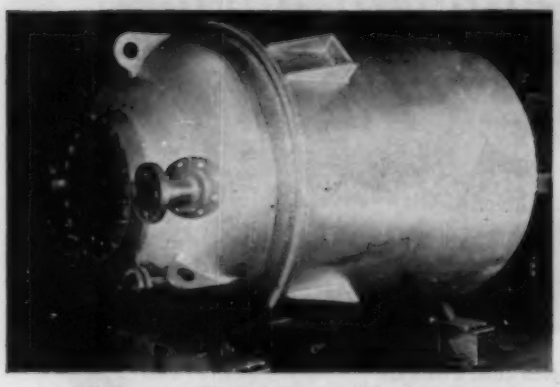

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Kansas City

from page 131

Vinyl Chloride from Acetylene and Hydrogen Chloride: Catalytic Rate Studies. R. D. Wesselhoft, J. M. Woods, & J. M. Smith, Purdue Univ. An experimental study of the rate of reaction of gaseous acetylene and hydrogen chloride.

An Analysis of Kinetic Data. Jerome Brewer & S. M. Walas, Univ. of Kansas. A new, concise, graphical method verifies or disproves kinetic mechanisms, evaluates rate constants and integral or fractional reaction orders.

WEDNESDAY, MAY 20

9:00 A.M. to 12 Noon

TECHNICAL SESSION NO. 13—ROLE OF WETTING AND CAPILLARITY IN FLUID DISPLACEMENT PROCESSES.

Chairman: C. S. Kuhn, Magnolia Petroleum.

Contact Angle Hysteresis on Aquagels. A. S. Michaels & R. C. Lummis, M.I.T. A study of contact angles of drops of methylene iodide on dilute agar aquagels in air.

Relative Wetting Tendencies of Crude Oils by the Capillarimetric Method. R. T. Johansen & H. N. Dunning, Bureau of Mines. Wetting tendencies of crude oils on reservoir rock.

Wettability as Related to Capillary Action in Porous Media. J. C. Melrose, Magnolia Petroleum. The role of the contact angle as one of the boundary conditions for the differential equation specifying the configuration of fluid/fluid interfaces.

Determination of Effective Capillary Pressures for Porous Media from Imbibition Data. L. L. Handy, California Research Corp. Two equations for calculating imbibition rates of water into porous media are compared.

TECHNICAL SESSION NO. 14—THE PRESENT STATUS OF LIQUID METALS TECHNOLOGY.

Chairman: H. M. Rodekohr, Ethyl Corp.

1500°F. Liquid Metal Heat Exchanger Development Program. C. C. Eckles, General Motors. Heat transfer and thermal shock performance for various heat exchanger designs.

Container Materials for Liquid Lead-Bismuth Mixtures. J. C. Clifford & G. Burnet, Jr., Iowa State College. Resistance of several ferrous alloys to attack by lead-bismuth eutectics in the 600 to 900°C. range.

Properties and Handling of Lithium. H. H. Schroeder, Lithium Corp. of America. Properties, corrosion, handling, storage, nuclear characteristics of lithium.

Handling Uranium-Bismuth Reactor Fuels. C. J. Raseman, R. J. Isler, C. J. Klamut, H. Susskind, & C. H. Waide, Brookhaven. Fabrication techniques, mechanical components, instrumentation.

2:00 to 3:30 P.M.

TECHNICAL SESSION NO. 15—ROLE OF WETTING AND CAPILLARITY IN FLUID DISPLACEMENT PROCESSES.

Chairman: C. S. Kuhn, Magnolia Petroleum.

Effect of Fractional Wettability on Multiphase Flow Through Porous Media. Irving Fatt & W. A. Klikoff, Jr., Univ. of Calif. Capillary pressures and relative permeability of unconsolidated sand shown to be functions of fractional wettability.

Effects of Crude Oil Components on Rock Wettability. M. O. Danekas & C. C. Mattax, Jersey Production Research Co., & G. T. Davis, Esso Research and Engineering. Wetting actions of fractions from three crude oils were measured.

2:00 to 5:00 P.M.

TECHNICAL SESSION NO. 16—PRESENT STATUS OF LIQUID METALS TECHNOLOGY.

Chairman: H. M. Rodekohr, Ethyl Corp.

Electrical Heating Methods for Liquid Metal Systems. R. S. Baker & H. W. Lohman, Atomics International. Compares resistance, induction, and transformer heating of various piping systems.

Mass Transfer in Liquid Lithium Systems. W. N. Gill, R. P. Vanek, R. V. Jelinek, & C. S. Grove, Jr., Syracuse Univ. Solution and deposition coefficients measured in a forced-convection lithium system correlated and compared with other reported systems.

Solubility of Iron in Liquid Lithium. J. J. Sand, W. N. Gill, R. V. Jelinek, & C. S. Grove, Jr., Syracuse Univ. Equilibrium solubility data up to 1,200°C. presented and analyzed to aid corrosion and mass transfer studies.

Pumps for Liquid Metals. A. P. Erwin, Allis-Chalmers. Current designs, projected requirements, design trends.

industrial news

Orlon acrylic fiber will be manufactured at Dordrecht, The Netherlands, by Du Pont. A planned subsidiary firm will build a plant with a capacity of 15 million pounds a year.

A new firm, Girdler-Suedchemie Katalysator G.mb.H. has been formed by Chemetron. The German affiliate is jointly owned by Chemetron and Suedchemie A.G., Munich

A new $4 million sodium chlorate plant went on stream at Aberdeen, Mississippi, recently. American Potash & Chemical's new unit has a capacity of 15,000 tons a year.

Magnesium fluoride slag containing 3% uranium is available for sale to industry. A by-product of the AEC's normal production, the uranium can be sold only to AEC licensed persons.

A Science-Engineering-Research Center has been made possible at the University of Denver with the grant of $1,250,000 from the Boettcher Foundation. Proposed name for the site is the Boettcher Center for Science, Engineering and Research of the University of Denver.

An electron beam furnace will be installed at the Albany, Oregon, plant of Wah Chang Corp. this spring. It has a 225 KW rating, and is capable of continuous melting and casting of high purity ingots. Experimental units have melted special steels, tungsten, molybdenum, uranium, columbium.

A UOP Butamer unit is under construction for installation at the Richmond refinery of Standard Oil of California. Production capacity is about 2,000 barrels a day of isobutane.

Ammonia production expansion by 20% is planned this year at Collier Carbon & Chemical Corp., Brea, California, plant.

A polyethylene film producing plant is under construction at Cartersville, Georgia, by Visking Company (Union Carbide).

Solid propellant rocket motors research and development will continue at Thiokol Chemical Corp. A contract awarded by the Army Rocket and Guided Missile Agency calls for delivery of an unspecified number of XM 33 models by the Redstone Division of the firm.

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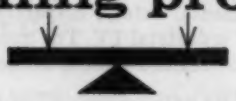

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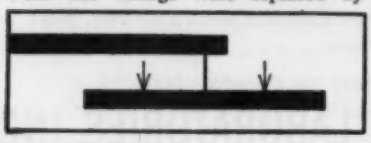

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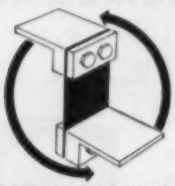

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future meetings

1959—MEETINGS—A.I.Ch.E.

• Cleveland, O. April 5-10, 1959. **Nuclear Congress. Co-sponsored by A.I.Ch.E. and others.** A.I.Ch.E. representative: E. B. Gunyou, Alco Prods., Inc., Schenectady 5, N. Y. (see Feb. CEP, page 86).

• Kansas City, Missouri, May 17-20, 1959. Hotel Muehlebach. **A.I.Ch.E. National Meeting.** Gen. Chmn.: F. C. Fowler, Consulting Chem. Engr., 7515 Troost Ave., Kansas City, Mo. Tech. Prog. Chmn.: Fred Kurata, Chem. Eng. Dept., Univ. of Kansas, Lawrence, Kansas. (See page 126.)

• Storrs, Conn. August 9-12, 1959. Univ. of Conn. **A.I.Ch.E.-A.S.M.E. Heat Transfer Conferences.** Prog. Chmn.: M. T. Cichelli, Eng. Research Lab., DuPont, Wilmington, Del.

• St. Paul, Minn., Sept. 27-30, 1959. Hotel St. Paul. **A.I.Ch.E. National Meeting.** Gen. Chmn.: W. M. Podas, Asst. Rsch. Dir., Economics Lab., Guardian Bldg., St. Paul, Minn. Tech. Prog. Chmn.: A. J. Madden, Jr., Univ. of Minn. **Mixing**—J. Y. Oldshue, Mixing Equip. Co., Inc. P.O. Box 1370, Rochester 3, N. Y. **Size Reduction**—J. W. Axelson, Johns-Manville, Manville, N. J. **Missile Construction Materials**—B. M. Landis, Missile Div. Lockheed Aircraft, Palo Alto, Calif. **Physical Properties of Liquids**—S. E. Isakoff, DuPont Co., Eng. Dept., Expr. Sta., Wilmington, Del. **Molecular Engineering**—M. Boudart, Princeton U., Chem. Eng. Lab., Princeton, N. J. **Chemical Economics as a Unit Process**—M. H. Baker, 1645 Hennepin Ave., Minneapolis 3, Minn. **More Research for Your Dollars**—T. S. Mertes, Sun Oil Co., 1608 Walnut St., Philadelphia 3, Pa. **Process Control**—I. Lefkowitz, Case Inst. of Techn., Cleveland, Ohio. **Chemical Warfare**—Co-Chmn.: L. E. Garono & E. J. Gruen, Army Chem. Corps, Bldg. 250, Baltimore, Md. **Safety in Air and Ammonia Plants**—W. A. Mason, Dow Chem. Co., Midland, Mich. **Management of New Product Development**—L. B. Hitchcock, Consultant, 60 East 42 St., New York 17, N. Y. **The Chemical Engineer and Professional Societies**—C. R. Ringham, Phillips Petroleum Co., Bartlesville, Okla. **Longitudinal Mixing**—J. R. Fair, Jr., Monsanto Chem. Co., Sta. B, Dayton 7, O. **Student Program**—A. G. Fredrickson, Chem. Eng. Dept., U. of Minnesota, Minneapolis, Minn. **Gen. Tech. Sessions.** Deadline for papers: May 27, 1959.

• San Francisco, Calif., December 6-9, 1959. **A.I.Ch.E. Annual Meeting.** Gen. Chmn.: Mott Souders, Jr., Shell Development Co., 4560 Horton St., Emeryville 8, Calif. Tech. Prog. Chmn.: C. R. Wilke, Div. of Chem. Eng., Univ. of Calif., Berkeley, Calif. **Process Dynamics**—E. F. Johnson, Dept. of Chem. Eng., Princeton U., Princeton, N. J. **Operations Research**—R. R. Hughes, Shell Dev. Co., Emeryville 8, Cal. **Progress and Problems in Jet and Rocket Combinations**—C. J. Marsel, NYU, University Heights, New York 53, N. Y. **Secondary Oil Recovery Methods**—F. H. Poettman, Ohio Oil Co., Littleton, Colo. **Financing in the Chemical Industry—Fundamental Aspects of Chemical Engineering in the Pulp and Paper Industry**—J. L. McCarthy, Dept. Chem. Eng., U. of Washington, Seattle, Wash. **Turbulence and Turbulent Mixing**—T. Baron, Shell Devel. Co., Emeryville, Cal. **Electro-Chemical Engineering**—C. W. Tobias, Dept. Chem. Eng., U. of Cal., Berkeley, Cal. **Outlook for National Resources**—C. Meyer, U. of Calif., Berkeley, Calif. **Student Program**—D. M. Mason, Stanford U., Stanford, Calif. **General Technical Session**—M. Manders, Union Oil Co., Rodeo, Calif. Deadline for papers: August 6, 1959.

1959—A.I.Ch.E. Local Section

• Philadelphia, Pa. March 31, 1959. **University Museum, 33rd & Spruce Sts., U. of Pa. 7th Annual All-Day Meeting Philadelphia-Wilmington Section A.I.Ch.E. Recent Advances in Chemical Engineering Practice.**

• Pittsburgh, Pa., April 10, 1959. Mellon Institute, 4400 Fifth Ave., Pitts. **Seminar type Catalysis Symposium. Joint One-Day Regional Meeting: Co-sponsored by Akron, Central Ohio, Cleveland, Detroit, No. West Va., Ohio Valley, Pittsburgh, & Toledo Sections A.I.Ch.E.**

• Linden, N. J. Apr. 2, 9, 16, 21, & 30, 1959 Esso Resch. Center Auditorium, Bldg. 1. **Lecture series on Kinetics.** Sponsored by N. J. **Section A.I.Ch.E.** For info. write M. L. Barry, Esso Res. & Eng. Co., Process Res. Div., P.O. Box 121, Linden, N. J.

continued on page 136

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future meetings

from page 134

1959—Non-A.I.Ch.E.

• **New York City, Mar. 23, 1959. Waldorf. IRE Professional Group on Eng. Writing & Speech.** A.I.Ch.E. invited. H. Lisk, Norden Labs., 121 Westmoreland Ave. White Plains, N. Y.

• **London, Apr. 29, 30, 1959. Convention on Thermonuclear Processes.** W. K. Brasher, Secy., The Institution of Elect. Engrs.

• **Wash., D. C. May 14, 15, 1959. Shoreham Hotel. 7th Ann. Mtg. Ops. Research Soc. of America.**

• **Los Angeles, Calif. June 22-26, 1959. Hotel Statler. Tech. Session, Air Pollution Control Assoc.**

• **Austin, Tex. Sept. 9-11, 1959. Univ. of Texas. Mid-West Conf. on Fluid & Solid Mechanics.** Co-sponsored by U. of Tex., A.I.Ch.E. & others. Tech. Chmn.: M. J. Thompson, U. of Tex. Abstr. & Titles by Apr. 1, 1959; complete MS by June 1, 1959.

1960—MEETINGS—A.I.Ch.E.

• **Atlanta, Ga. Feb. 21-24, 1960. A.I.Ch.E. National Meeting.** Gen. Chmn., J. W. Mason, Dean, Coll. of Eng., Georgia Tech. Tech. Prog. Chmn.: F. Bellinger, Georgia Tech., 223 North Avenue N. W., Atlanta 13, Ga. **Kinetics**—C. D. Holland, Chem. Eng. Dept., Texas A&M, College Sta., Texas. **Pesticides** (2 sessions) D. J. Porter, Diamond Alkali, Box 348, Painesville, Ohio. **Nuclear Engineering; Petroleum, Turpentine, and Solvents; Rubber and Plastics Applied to Textile Fibers;** John Warner. **Bioengineering-Radioisotopes; Pulp and Paper; Engineering Sales; Rockets and Missiles**—R. B. Filbert, Jr., Battelle Mem. Inst., 505 King Ave., Columbus, O. **Management of Small Plants; Engineering Education; Mineral Engineering**—W. A. Koehler, West Virginia U., Morgantown, W. Va. **Fundamentals.**

• **Mexico City, Mexico, June 19-23, 1960. A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: G. E. Montes, Nat'l Petrochemical Corp., P.O. Box 109, Tuscola, Ill. **Chemical Engineering in Latin America**—John Mayurnik, Grace Chem. Co., 3 Hanover Square, New York 4, N. Y. **Petroleum Production**—F. W. Jessen, Dept. Petroleum Eng., U. of Texas, Austin, Tex. **Minerals and Metals**—D. B. Coghlan, Foote Mineral Co., Lancaster Ave., Berwyn, Pa. **Distillation Equipment**—R. Katzen, 3735 Doswood Lane, Cincinnati, O. **Biochemicals and Foods; Gen. Tech. Sessions.**

• **Tulsa, Okla., Oct. 2-5, 1960. A.I.Ch.E. National Meeting.** Gen. Chmn.: E. W. Kilgren, P.O. Box 591, Tulsa, Okla. Tech. Prog. Chmn.: K. H. Hachmuth, Phillips Petroleum Co., Bartlesville, Okla. **Foams—Their Use and Control**—C. S. Grove, Jr., Syracuse U., Collendale, Syracuse 10, N. Y. and R. L. Tuve, U. S. Naval Resch. Lab., Washington 25, D.C. **Computer as a Management Tool**—R. Cxiner, Grace Chem. Co., 3 Hanover Square, New York 4, N. Y. **Chemical Reactions Induced or Modified by Radiation**—J. J. Martin, Dept. Chem. Eng., U. of Mich., Ann Arbor, Mich. **Transport Processes in Petroleum Recovery; Advances in Refinery Technology; Petrochemicals, Natural Gas, and Natural Gas Liquids; Pilot Plants and Scaleup; Corrosion and Materials of Construction; Statistics and Numerical Methods Applied to Engineering; Comparative Economics of Various Energy Sources for Process Heat; Safety in Air and Ammonia Plants; Safety in Refinery and Natural Gasoline Plants; Area Industries; Conservation and Utilization of Water.**

• **Washington, D. C., Dec. 4-7, 1960. A.I.Ch.E. Annual Meeting.** Gen. Chmn.: J. L. Gilliman, Jr., 1700 K St. N.W., Wash. 6, D.C. Tech. Prog. Chmn.: D. O. Myatt, Atlantic Research Corp., Alexandria, Va.

1960—MEETINGS—Non-A.I.Ch.E.

• **Moscow, USSR, June, 1960. 1st Congress of** International Fed., Automatic Control. To cover **areas of Theory, Hardware & Applications of automatic control.** U.S. participation sponsored by American Automatic Control Council. Affiliated societies: **A.I.Ch.E., ASME, AIEE, IRE, ISA.** A.I.Ch.E. Chmn.: D. M. Boyd, Universal Oil Prods., Des Plaines, Ill. completed papers by July 15, 1959.

1961—MEETINGS—A.I.Ch.E.

New Orleans, La. Feb. 19-22, 1961. Tech. Prog. Chmn.: Malakoff. Kinetics of Catalytic Reaction; Brainstorming Technical Problems; Petrochemicals—Future of the Industry on Gulf Coast; Solids—Handling and Mixing; Future Processing Technology in the Petroleum Industry; Education and Professionalism; Mathematics in Chemical Engineering; Liquid—Liquid Extractions; New Processes in the Area; Water from Sea Water.

Unscheduled Symposia

Correspondence on proposed papers is invited. Address communications to the Program Chairman listed with each symposium below.

Computers in Optimum Design of Process Equipment: Chen-Jung Huang, Dept. of Chem. Eng., Univ. of Houston, Cullen Blvd., Houston 4, Texas.

Preparation of Catalytic Cracking Charge Stocks and Quality Criteria Therefore: Wheaton W. Kraft, Lummus Co., 385 Madison Ave., New York 17, N. Y.

Solar Energy Research: J. A. Duffie, Director of Solar Energy Laboratory, Univ. of Wisconsin, Madison, Wis.

Hydrometallurgy—Chemistry of Solvent Extraction: G. H. Beyer, Dept. of Chem. Eng., Univ. Mo., Columbia, Mo.

Process Dynamics as They Affect Automatic Control—D. M. Boyd, Universal Oil Prods., Des Plaines, Ill.

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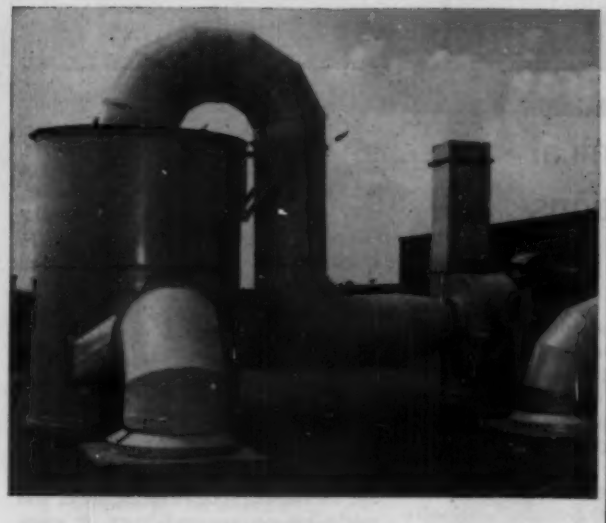

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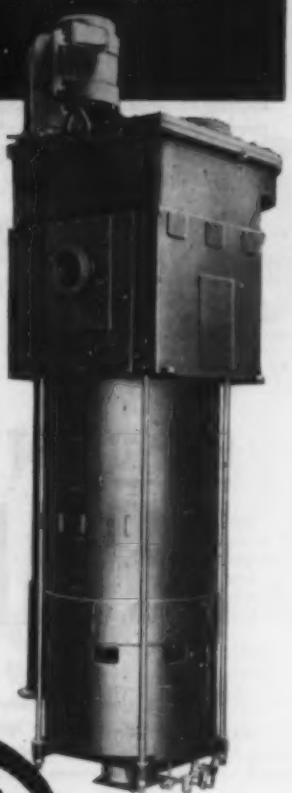

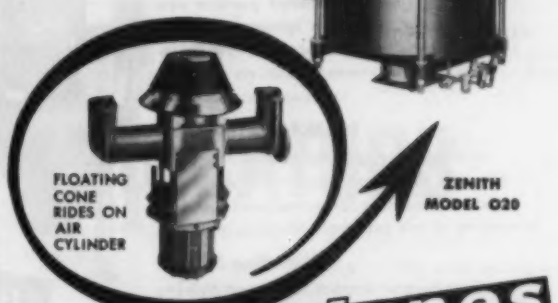

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Engineer shortage, chemical propellants, at Local Sections

While slight dips in the demand curve for engineers have occurred recently, the long range forecast is for ever increasing need for men in the field. This was the consensus among four panelists* who discussed "Are There Too Many Engineers" at the **Philadelphia-Wilmington Section** (*Bernard A. Rausch*) meeting in December.

National Science Foundation figures were quoted by Lewis, in predicting a shortage of 125,000 engineers by 1965. Cavanaugh pointed out that U.S. industry employs about 40,000 men classified as engineers but without formal education as such. Industry has been forced to use these men as engineers because of a manpower shortage. In the opinion of McCabe, there will always be a shortage of engineers. Engineers themselves do not appear to be aware of the overall picture, according to Kirkpatrick, and about half of 1600 chemical engineers surveyed recently believed there was no undue shortage.

All four panelists agreed that the need for larger numbers of well qualified engineers will grow, and effort is required from educational institutions, and from all of us, to guarantee that our technological progress is not stifled because of a lack of engineering manpower.

The role of the appraisal engineer, and what management wants when it asks for an appraisal, was the subject of an address "Corporate Economics and Finance", by Charles F. Parker, vice president of Union Oil, to the **Southern California Section** (*P. F. Lueth*) in September. An appraisal report should show total capital investment, annual profit, relationship of profit to investment. It should discuss reliability of assumptions used, factors such as risks, competition and obsolescence, as well as major intangibles. Requirements such as cost of auxiliary facilities, land and rights of way, allowance for working capital, are all musts. When the engineer has made his recommendations, if management does not act upon them, he should review his analysis. If he still believes in the earlier recommendations, he has a responsibility to seek a new hearing. And, if still over-ridden, the engineer must understand that business management is not a precise science, nor can business decisions be fixed entirely by mathematics.

P. Burdette Lewis, Du Pont; William Cavanaugh, Engineers Joint Council; Warren L. McCabe, Polytechnic Institute of Brooklyn; moderator, Sidney Kirkpatrick, McGraw-Hill.

Chemical propellants

"At the present time the only available source of energy for space travel resides in chemical propellants," according to Irvin Glassman, professor of Aeronautical Engineering at Princeton. "And for the next ten years it is not expected that any other source could be considered practical," Glassman told a joint meeting of the **Maryland sections** of A. I. Ch. E. and ACS (*Phil Messina*). It is well to recognize that fuel requirements vary with the specific use of the rocket, viz: astronautical vs. terrestrial systems. In support of this, he cited that hydrogen peroxide would probably be exceptionally good for astronautical systems because the decomposition of the fuel would provide water and oxygen for the rocket ship inhabitants; whereas this requirement would not exist for a terrestrial weapon system.

The important consideration in choosing a fuel for space travel is its specific impulse—a value proportional to the square root of the combustion temperature divided by the mass of the combustion products. This means that a very desirable fuel would be a high density material of low molecular weight.

The simplest and best known fuel system, Glassman said, is the combination of liquid oxygen and gasoline,

continued on page 140

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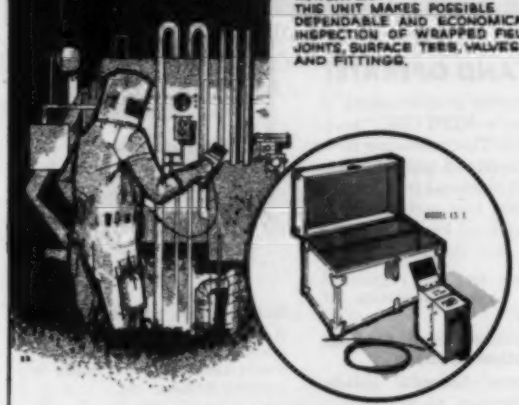

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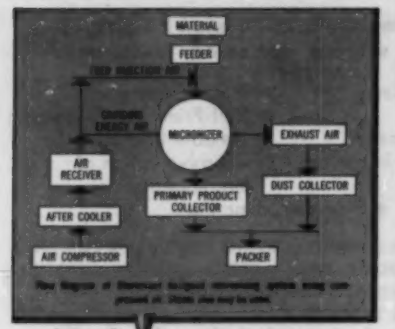

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with a specific impulse of about 256 seconds at 300 lb./sq. in. chamber pressure. This will probably be sufficient for rockets used to place satellites in orbit, but is low for rockets required to escape the earth's gravitational field. Liquid oxygen + liquid hydrogen has a specific impulse of 390 sec at 1000 lb./sq. in. Liquid hydrogen has very good heat transfer properties, but has the disadvantage that both oxidizer and fuel must be handled at very low temperatures. Available oxidizers tested to date, in order of promoting highest specific impulse, are: O_3, F_2, F_2O, NF_3, O_2, ClO_2F, ClF_3, H_2O_2, N_2O_4, $C(NO_3)_4$, HNO_3, BMF_3.

However, some of them cannot be used. For instance, ozone, (by far the best oxidizer known), is difficult and dangerous to handle, even at low concentrations. In general, fluorine appears to be the most practical oxidizer choice, and a liquid H_2-liquid F_2 system appears to have the attractive specific impulse of 410 seconds. In addition, any system using liquid fluorine as an oxidizer is completely hypergolic (ignites spontaneously in presence of oxidizer, and maintains combustion after source of ignition is removed).

In a brief comparison between liquid and solid fuels, Glassman noted that liquid systems are much better for carriers which must escape the earth because of higher specific impulse. Solids are very stable and generally easy to handle, but in all cases show less performance than liquid systems. A major problem with solid fuel is the proper blend of oxidizer and fuel.

Glassman also discussed other possible methods of developing thrust, mentioning that free radicals in potential rocket systems impose problems which are generally insurmountable. And, in the forseeable future, we will probably not use free radicals as a source of energy. Similarly, ion machines appear practical only after the escape from all gravitational fields has been achieved.

continued on page 141

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local sections

from page 140

With the issuance of a questionnaire entitled "What's A.I.Ch.E. Doing for You?" members of the **South Texas Section** (*W. J. Domosk*) are being given an opportunity to express themselves on the work of the Institute. Attitudes toward professional problems such as state registration of chemical engineers and collective bargaining, are taken up. The questionnaire also contains sections for members to rate A.I.Ch.E. performance, suggest what the Institute should do in terms of serving the needs of the profession, and give ideas for new activities or projects. Results of the survey will be discussed with the Council at the Atlantic City meeting.

New Sections

The Southwestern Washington Section is a new addition to A.I.Ch.E. The section, to which president Katz presented the charter at a meeting on January 23, has as its officers: chairman, Dale Sorenson; secretary-treasurer, H. E. Hendrickson; R. O. Bathiany, executive committee member. E. L. Soule is chairman-elect for 1960.

The Indianapolis Association of Chemical Engineers was officially welcomed into the ranks by F. J. Van Antwerpen on January 20 at the charter meeting. Officers are: chairman, John LaBash; vice chairman and head of membership committee, Robert E. Avels; program committee, J. M. Woods; William S. Johnston, secretary-treasurer.

Also meeting

The labor point of view was aired by O. A. Knight, president of the Oil, Chemical and Atomic Workers, AFL-CIO, at the January **Oklahoma Section** meeting (*R. C. Harrison*). . . . The advantages of Chemical Engineering as a career was explained to approximately 100 students by James D. Moore, Chairman of the **Great Salt Lake Section** (*M. E. Felkner*). . . . The annual Career Guidance Program Meeting of the **Texas Panhandle Section** (*J. B. Wallace*), for interested high school and college students, took place in November. . . . Digital Control Computers was the subject under discussion at the dinner meeting of the **Pittsburgh Section** (*V. N. Hurd*) in February. Ray J. Stanish of Thompson-Ramo-Wooldridge was the speaker. . . . **East Tennessee Section** (*J. C. Umberger*) meeting in November

continued on page 142

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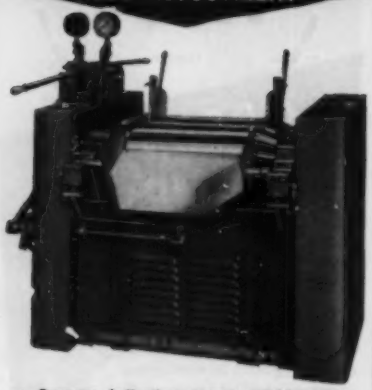

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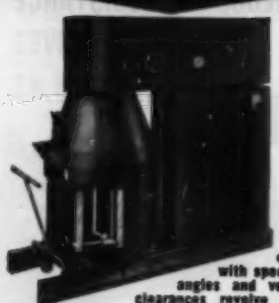

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local sections

continued from page 141

heard Paul Cohen, of Westinghouse, talk on the Shippingport pressurized water reactor.

Reactor design

A series of lectures on Chemical Reactor Design will be held by the **New York Section** (*H. Krinsky*) starting March 24. Subjects to be covered are: Fluid-Bed Reactor for Iron Ore, Arthur M. Squires; Transport Reactor, Nicholas A. Weil; Design of Non-Isothermal Chemical Reactors, Robert S. Davis; Optimization of Fixed-Bed Reactors, John Happel; Mixed Liquid-Phase Reactors, Arthur Weber; Reactor Instrumentation for Continuous Analysis, Abraham Savitsky. Sessions are scheduled for six consecutive Tuesday evenings at the Chrysler building.

Coatings containing butadiene-acrylonitrile copolymer and phenolic resin provide satisfactory protection for steel against effects of gasoline and moisture, according to a report of Army research. Title is "Investigation of various metal protective coatings on the gum formation and oxidation stability of gasoline."

International distribution of Ansul products will be handled by Ansul International Corp., S.A. The new subsidiary will provide service to foreign customers and develop foreign markets.

Polyurethane flexible foam production facilities will be increased six-fold at Nopco Chemical. Plans call for the present plant in North Arlington, N. J., to triple in size when present construction is completed.

Uranium impregnated graphite samples will be developed by Brookhaven Lab, according to a contract awarded them by Nuclear Development Corp. A capsule for irradiation in the MTR at Idaho will be fabricated in a thermal neutron flux in excess of 1 x 10^{14}n/cm^2-sec at controlled temperatures of 900°F.

A further expansion of ammonium perchlorate facilities on tap for Pennsalt Chemicals at Portland, Oregon. Plans call for increase in capacity by several thousand tons, along with a 25% increase in the adjacent sodium chlorate unit.

ACID VAPORS Strangled by MULTI-WASH

These vats are giving off harmful acid vapors that could affect workers' efficiency and contaminate air in the neighborhood.

The management of this plant has eliminated these dangerous vapors and the health hazard by using efficient Multi-Wash Collectors.

Each vat is hooded to take away vapors to special Multi-Wash units, lined with acid resistant material to prevent corrosion. There, acid vapors are mixed with a neutralizing liquid to render them harmless.

If your process presents problems in obnoxious vapors, fumes or dusts, contact your local Schneible representative or call us direct.

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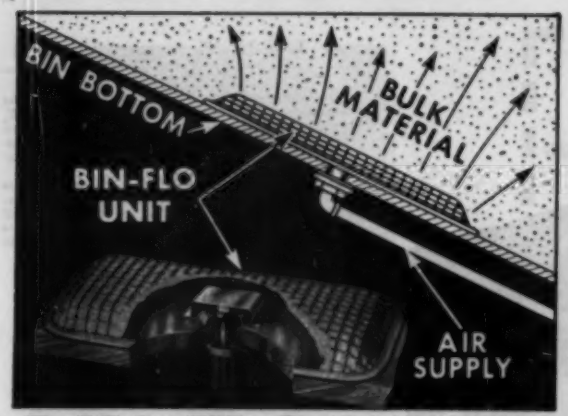

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USES SMALL VOLUME OF AIR AT LOW PRESSURE

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BIN-FLO units in bins, chutes, hoppers, etc., restore flow characteristics to dry, finely ground materials which tend to pack or bridge in storage. Types for all materials and conditions. No moving parts; simple installation; negligible operating cost; no maintenance cost.

BIN-DICATOR the original diaphragm-type bin level indicator. In successful use for over 20 years. **ROTO-BIN-DICATOR** new, motor-driven paddle type; excellent on bins under pressure or vacuum, and for general application. Also explosion-proof units, U.L. listed.

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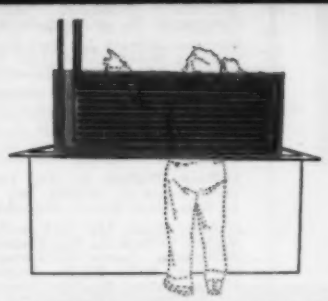

Old-fashioned pipe coils are obsolete. Above is shown a typical example of the ease with which the

DEAN THERMO-PANEL COIL

is handled. It **TAKES THE PLACE** of pipe coils because it contains much more heating surface per sq. ft. Occupies less space. Is more efficient. More economical. More quickly installed and removed for cleaning. And the first cost is usually much less.

EVERY CHEMICAL ENGINEER

who has heat transfer problems should ask for complete data, including prices, on this money-saving modern product. You can then do your own designing and cost estimating. Should you need help, call on Dean's specialists.

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Many Money-Saving Applications — The Smith-Dolan System simplifies and upgrades work quality in numerous applications ranging from welding to forming and annealing. Units are available for 60 cycle heating in capacities ranging from 10 to 150 KVA . . . for 400 cycle heating . . . resistance heating. Pre-engineered with complete instrumentation, accessories.

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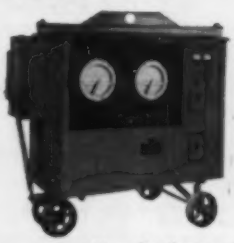

Electronic recording gives permanent charts of heat run on this standard Smith-Dolan model. Coils permit work at 50 feet or more from unit. Eye hooks provide for easy handling by crane. Products ranging from a fraction of an inch to 10 feet in diameter can be heat treated on the job.

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While chromium and nickel in varying proportions are the principal alloying elements in most high alloy castings, sometimes operating conditions call for several alloying elements and knowledge of how to use them to bring out certain special characteristics.

In our thirty-five years of high alloy casting experience we have encountered and solved some very difficult corrosion — temperature — strength problems. Perhaps we can help you in connection with your high alloy casting requirements.

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A. I. Ch. E. candidates

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions. These names are listed in accordance with Article III, Section 3 of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members and Associate Members will receive careful consideration if received before April 15, 1959, at the office of the Secretary, A.I.Ch.E., 25 West 45th Street New York 36, N. Y.

MEMBER

Avery, W. B., *Cambridge, Mass.*

Boswell, B. Clifford, *Kingsport, Tenn.*
Boyd, Worthy T., *Baton Rouge, La.*
Breitmayer, Theodore, *Glendora, Calif.*

Campbell, Peter F., *Elizabeth, N. J.*
Castiglioni, Bruno P., *Houston, Tex.*
Chamberlin, M. H., *Nutley, N. J.*
Cipolla, Richard H., *New York, N. Y.*
Coggeshall, Alva C., *Pensacola, Fla.*
Craig, Robert L., *Pittsburgh, Pa.*

Fuchs, Oscar A., Jr. *Elderado, Ark.*

Kapp, L. F., *Chicago Heights, Ill.*
Knudsen, James G., *Corvallis, Ore.*

May, John R., *Phoenix, Ariz.*

Philoon, Wallace C., Jr., *St. Louis, Mo.*
Price, P. Charles, *Garden Grove, Calif.*

Van Vorst, Wm. D., *Los Angeles, Calif.*

Whyte, David D., *Cincinnati, Ohio*

Yost, John R., Jr., *New Brunswick, N. J.*

ASSOCIATE

Arnold, David W., *Dundee, Miss.*
Atchison, Hugh C., *Boulder, Colo.*

Beard, James H., *Silas, Ala.*
Bechter, Paul W., *Houston, Tex.*
Biggers, Egbert Wendell, *Baytown, Tex.*
Bogeatzes, Andy S., *Rochester, Pa.*
Boumans, Donald T., *Orange, Tex.*
Broussard, George, *Alton, Ill.*
Burkhart, Lawrence E., *Ames, Iowa*

Capano, Vincent J., *New Castle, Del.*
Caro, Paul M., *Niagara Falls, N. Y.*
Chaffin, Sammy L., *Fayetteville Ark.*
Chiang, Shiao-hung, *Buffalo, N. Y.*
Connell, Edward Dodd, *Fayetteville, Ark.*
Coppo, Richard H., *South San Francisco, Calif.*

Dagle, Richard E., *Pensacola, Fla.*
Dawn, William S., *Battle Creek, Mich.*
Doctor, Lewis J., *Brookline, Mass.*
Dzingala, Walter, *Newark, N. J.*

Engelmann, Alfred P., *Wilmington, Del.*

Fleming, J. D., Jr., *Atlanta, Ga.*

Garrison, Richard L. *Port Neches, Tex.*
Gilliland, Bobby E., *Rayville, La.*
Grimsrud, Thomas J., *Houston, Tex.*

Harrington, H. Richard, *Sandersville, Ga.*
Hovey, Leonard L., *Harbor City, Calif.*

Kikuchi, R., *Vancouver, B. C., Canada*
Koller, James C., *Chicago, Ill.*
Kresge, A. Norman, *Pittsburgh, Pa.*

Lafferty, William L., Jr., *Fishkill, N. Y.*
Lahti, Leslie E., *Angola, Ind.*
La Rue, Clyde B., Jr., *Warwick, Va.*

Mallory, Hugh, III, *Port Arthur, Tex.*
Marlar, Clifford H., Jr., *Texarkana, Tex.*
McNicholas, James J., *Curwensville, Pa.*
Morrison, Willie H., Jr., *Fayetteville, Ark.*
Moyses, Harvey M., *New Haven, Conn.*

Parkey, William R., *Texas City, Tex.*
Pender, John Lawrence, *Hot Springs, Ark.*
Peralta, Bernal, *Los Angeles, Calif.*

Reinhold, Curt, *New York, N. Y.*
Rich, Robert S., *Louisville, Ky.*
Rosenhouse, Harvey, *Newark, Del.*

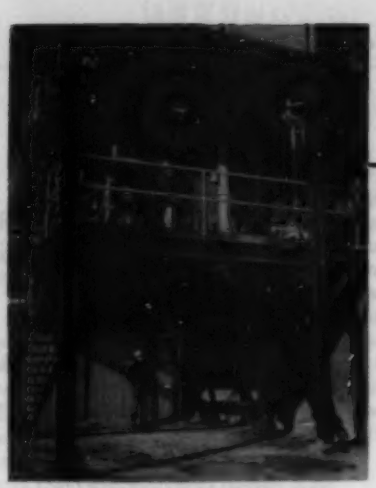
Schallhorn, David, *DeWitt, Ark.*
Scheirman, Charles C., *Oklahoma City, Okla.*
Sherwood, Norman C., *Cloquet, Minn.*
Slattery, Gerald H., *Baltimore Md.*
Spencer, Richard K., *Port Arthur, Tex.*
Stockham, John K., *Akron, Ohio*
Szabo, Laszlo, *Boston, Mass.*

Taylor, Glenn E., *Baytown, Tex.*
Teckienburg, Harry, *Cincinnati, Ohio*
Tockes, Barna, *San Rafael, Calif.*

Venarde, Jack H., *Wilmington, Del.*

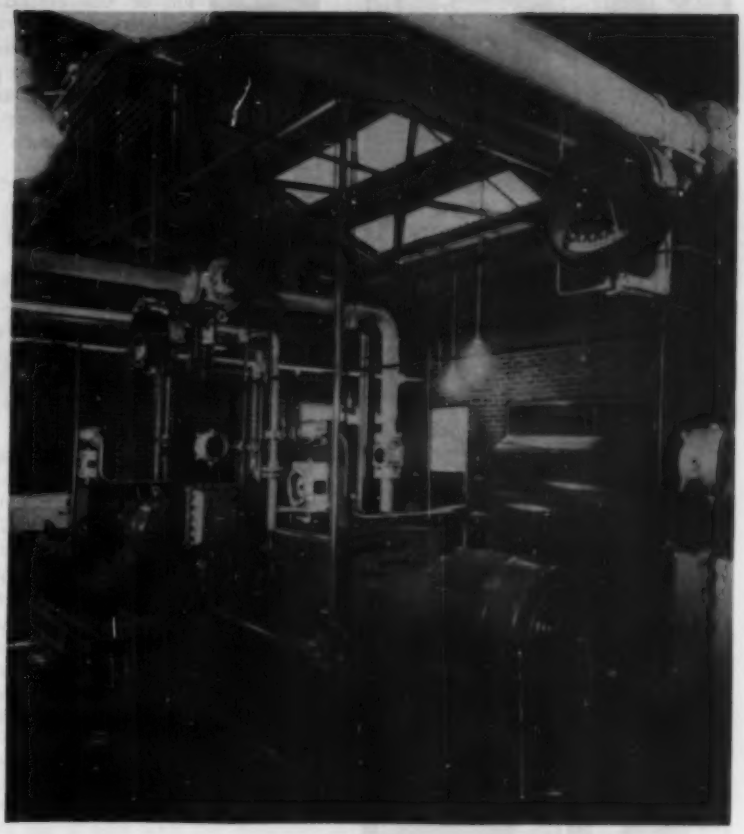
Wagner, John, Jr., *Narberth, Pa.*
Werder, Edward R., *Bayonne, N. J.*
Widner, Allen G., *Pittsburg, Kan.*
Willis, H. Earl, Jr., *Port Neches, Tex.*
Wonders, John S., *Florissant, Mo.*
Wright, Michael G., *Tulsa, Okla.*

Zanotti, Martin P., *Haddon Heights, N. J.*
Zufelt, John M., *Montague, Mich.*



Air pollution—A modern tubular air filter system at Solvay's (Allied) Syracuse plant has been recently installed to handle 25,000 cu. ft. of air a minute, has overcome a serious problem of lime dust discharging into the air.

New applications in pollution control



Water pollution—Facilities at right have been designed by Semet-Solvay (Allied) to recover over 97 percent of the phenol effluent from its Harriet plant at Tonawanda N. Y. Object was to control water pollution in the Lake Erie-Niagara River basins.

New Engineers Club in Connecticut

Organizing meeting of the new Fairfield County (Conn.) Chemical Engineers Club had the fine turnout of over 150 engineers (left). On hand to welcome the embryo section was A.I.Ch.E. past-president Sid Kirkpatrick. (Above, l. to r.) Herb Schoen, chmn.; Sid; Art Weinberger, membership; Roland Voorhees; Bill Quinlan, publicity. Dorr-Oliver, Stamford, was host.

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people in management & technology

Jesse Werner elected vice president of General Aniline & Film. Werner, formerly director of commercial development of the company's Dyestuff and Chemical Division, is author of forty-five publications and patents on various phases of chemical engineering and organic chemistry. He has been with General Aniline since 1938.

W. J. Magers appointed general supervisor of SunOlin Chemical's proposed urea plant. Magers will serve as operating consultant to the Engineering Group until he takes charge of the 73,000 ton a year plant, scheduled for completion in late 1959.

John F. Kunc has become senior research associate of Esso Research & Engineering. Kunc, a veteran of 32 years with the company, heads the Products Research Division's work on fuels and nuclear radiation application to product quality problems.

David M. Boyd and **Joel O. Hougen** were among the lecturers at recent sessions of the University of Wisconsin's Engineering Institute on *Automatic Control for Process Industries.*

Robert S. Buffum joins Comstock & Wescott as senior staff member. He will work with projects of a chemical processing nature.

General Electric Company has assigned **Francis K. McCune** to the new post of vice president-Atomic Business Development in Marketing Services. McCune, considered the company's top atomic expert, has been with GE more than 30 years. **Lyman R. Fink** succeeds him as general manager of the Atomic Products Division. Headquarters of both men are in Schenectady, New York.

Gunther Baldauf named research manager of Allied Paper Corp., Kalamazoo Mills. He was formerly research chemical engineer at Olin-Mathieson Chemical, Ecusta Paper Division.

C. B. Branch (left) named manager of Dow Chemical Company overseas and foreign activities, except Canada and Mexico. Branch has also been named president of Dow Chemical International Ltd. S. A., newly formed Dow subsidiary. **W. C. Goggin** succeeds to the post of manager of the Plastics Department.

David R. Boylan, professor of chemical engineering at Iowa State College, becomes associate director of the schools' Engineering Experiment Station.

Frank J. Soday named director of new research and development program at General Dynamics' Liquid Carbonic Division. Soday comes to General Dynamics from Chemstrand Co., where for seven years he was vice president of research and development.

Structroglas Division of International Molded Plastics has appointed **Richard L. Dreher** plant manager of its new 35,000 square foot factory in Grand Junction, Tennessee.

John G. Armistead transferred to the Wilmington headquarters of Du Pont's Elastomer Chemicals Department, on special assignment to the department's manufacturing division. **Harry B. Eaton** succeeds to post of manager of the Montague, Michigan, Works.

Norman R. Cox, Robert G. Kelso, and **Fred W. Stone** appointed group leaders in the Development Department of Union Carbide Chemicals, at South Charleston, West Virginia.

continued on page 147

SERV-RITE

thermocouple extension wire in

MULTI-PAIR CABLE

it cuts installation costs

When four or more pairs of thermocouple extension wires are needed, SERV-RITE thermocouple extension cable will reduce installation costs several ways. It takes considerably less time compared to pulling individual pairs of wires through conduit. Cable also permits the use of much smaller conduit than for the same number of individual wires. It can be hung without conduit, or installed in open trough or by direct burial.

The cable, as well as each conductor, is color coded. Also, each pair of wire is marked for quick identification.

Cables with multiple pairs of four or more conductors of the commonly used types are carried in stock.

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For more information, circle No. 30

people in management & technology

from page 146

James B. Fisk elected president of Bell Telephone Laboratories. Formerly executive vice president, Fisk has been with Bell nearly 20 years. He has served on several government committees, including President Eisenhower's Science Advisory Committee. He succeeds **Mervin J. Kelly**, who becomes chairman of the board of directors. **Estill I. Green** has been named executive vice president.

Warren P. Scarrah joins California Research Corporation's Richmond Laboratory as research engineer.

William H. Rader named petrothene polyethylene production manager for U. S. Industrial Chemicals (National Distillers).

A. W. Hogeland promoted to assistant chief plant engineer at American Viscose's Fredericksburg, Va. cellophane plant.

John H. MacDonald appointed superintendent of the Lyndhurst, New Jersey, plant of S. B. Penick & Co.

Joseph R. Gaskins has joined the Tonawanda Laboratories of the Linde Co. (Union Carbide) as a member of the Molecular Sieves Production and Development Laboratory. **Henry W. McRobbie** is now with the Research Lab's Market Research Section.

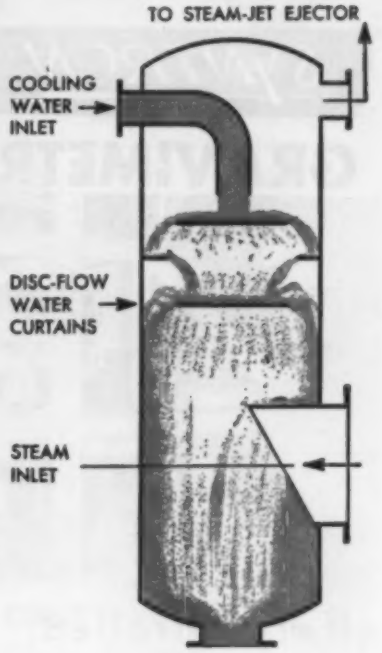
Edward A. Yorkgitis named group leader in the Chemical Research and Development Department of Hagan Chemical & Controls.

U. S. Industrial Chemicals has named **Ralph M. Knight** manager of polyolefin planning and applications. Headquarters are in Tuscola, Illinois, where Knight will direct the company's polymer service laboratories.

Coleman J. Major is new professor of chemical engineering at the State University of Iowa.

continued on page 148

How to
CONDENSE STEAM
and
PULL A VACUUM
at
LOW COST



I-R Disc-Flow Barometric Condensers provide a simple and low-cost method for condensing steam and creating a vacuum wherever condensate is expendable. Their high efficiency, simplicity of operation and overall economy make them ideal for use with steam engines, turbines, vacuum pans and a wide range of high-vacuum processes.

Since there are no water nozzles or small openings, they can be used where cooling water contains debris. For operation at partial loads, water flow can be reduced to as low as ⅓ of full capacity. Steam-jet ejectors or vacuum pumps can be supplied in ample size for all air-removal requirements.

Ejector-jet type units are also available.

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For more information, circle No. 100

from page 147

R. Tesoro and **R. H. Darling** named as assistant plant managers at Jefferson Chemical. Tesoro will be in charge of operations; Darling will supervise engineering, construction and maintenance at Port Neches, Texas. **E. R. Cobb** becomes chief processing engineer, and **C. H. Moore** is new chief engineer, Engineering and Maintenance Division.

E. C. Emanuel (left) takes over as manager of Customer Technical Services, Armstrong Cork Company Glass and Closure Division's new department. **John M. Scharf** moves into the post of general manager of Glass and Closure Products Research.

William H. Ceckler joins Jones & Laughlin Steel Corp. as chemical engineer.

George Thodos, professor of chemical engineering at Northwestern University, has become a member of the industrial and engineering chemistry advisory board of the American Chemical Society.

Thomas B. Nantz (left) steps into the position of vice president of manufacturing at B. F. Goodrich Chemical, succeeding **Robert D. Scott.** Scott is now vice president of development.

Robert K. Multer elected president of Architectural Tiling Company, moving up from vice president.

Among several changes in American Oil's Research and Development Department are: **F. M. Jacobsen** and **F. E. James, Jr.,** new senior chemical engineers, and **R. L. Stack,** administrative supervisor.

Standard Oil (Indiana) personnel recently given new assignments in research and development are: **Arthur L. Conn,** technical service; **William F. Meehan,** process development, and **Robert A. Steel,** process design and economics.

Neal R. Amundson elected an additional director of Midwest Technical Development Corp., Minneapolis investment firm.

people in marketing

Allen I. Barry appointed New England sales representative for Infilco, Inc., with headquarters in Milton, Massachusetts.

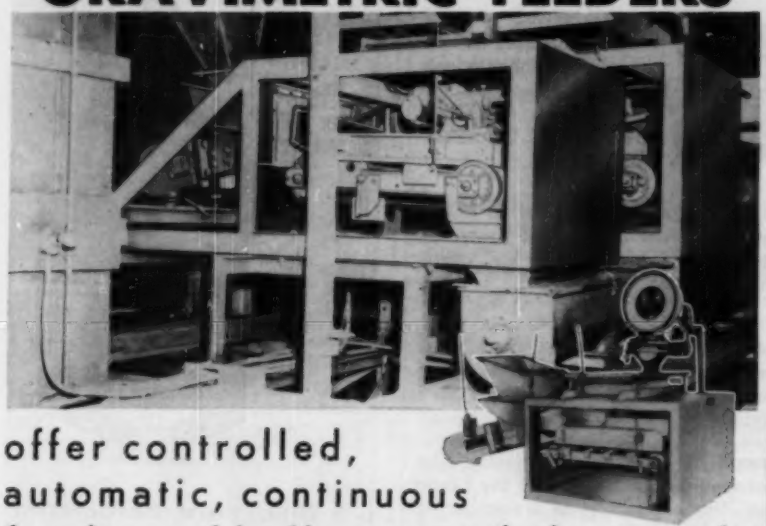
J. D. Steinhagen made sales engineer, molecular sieves products, for the Linde Company Western Region. Office is in Los Angeles.

Appointment of **Solon D. Fisher** as manager of the St. Louis, Missouri, sales branch announced by Solvay Process Division, Allied Chemical.

continued on page 152

SYNTRON "weigh-flow"

GRAVIMETRIC FEEDERS



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SYNTRON Gravimetric Feeders are available in a standard range of styles and sizes with capacities from a few pounds to 100 tons per hour.

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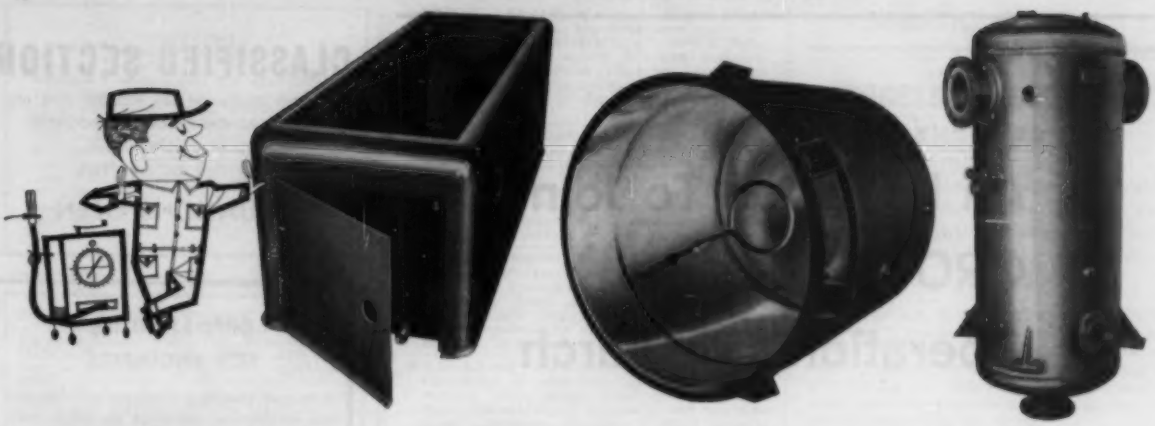

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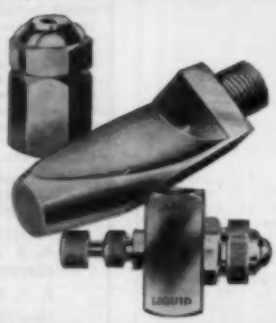
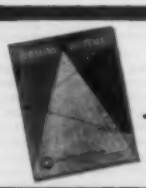
Your inquiry is invited.





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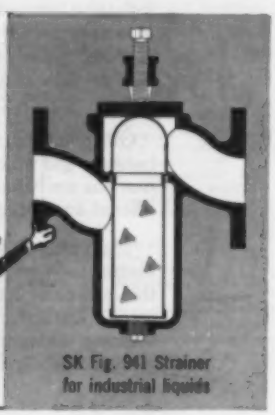

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The Fig. 941 has a cast iron body and cover, ductile iron clamp, stainless steel basket. Six inch size has a bolted cover. Baskets have ⅛ inch diameter holes; free pipe area is 5 to 1 in all sizes. Available with mesh liners for finer straining—stainless steel case then provided with ⅛ inch holes.

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ADVANCE INFORMATION

The Situations Wanted portion of this Classified Section is preprinted and mailed a few days in advance of publication, to Employment Directors. Send names of individuals who should be on mailing list to: Miss E. Adelhardt, Chemical Engineering Progress, 25 W. 45th Street, New York 36, New York.

CLASSIFIED SECTION RATES

Advertisements in the Classified Section are payable in advance at 24c a word, with a minimum of four lines accepted. Box number counts as two words. Advertisements average about six words a line. Members of the American Institute of Chemical Engineers in good standing are allowed one six-line Situation Wanted insertion (about 36 words) free of charge a year. Members may enter more than one insertion at half rates. Prospective employers and employees in using the Classified Section generally agree that all communications should be acknowledged as a matter of courtesy but recognize circumstances where secrecy must be maintained. (Usually a plain sheet saying "Box No. — thank you for your response and will write again if interested further" is better than no response). Answers to advertisements should be addressed to the box number, Classified Section, Chemical Engineering Progress, 25 West 45th Street, New York 36, N. Y. Telephone COlumbus 5-7330. Advertisements for this section should be in the editorial offices the 10th of the month preceding publication.

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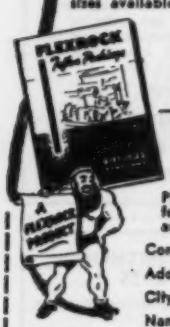

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people in marketing

continued from page 148

Charles G. Walker joins the Development Department of Procter & Gamble's Food Division.

C. E. Brown promoted to the post of manager, Marketing Department at Koppers Company, Tar Products Division.

Ralph L. Herbst, Jr. joins Pennsalt Chemicals, Technical Division, as supervisor of market development. Assisting him will be **G. H. Edward Walden.**

Henry E. Wessel joins Stauffer Chemical as assistant director of the Market Development Department.

Recently elected officers of the National Association of Corrosion Engineers are: president, **Hugh P. Godard,** Aluminum Laboratories, and vice president, **George E. Best,** of Solvay Process Division, Allied Chemical.

Additions to the technical staff of Atlantic Research Corporation are **James D. Batchelor,** Kinetics and Combustion Division; **David D. Dudley,** Solid Propellant Division.

W. R. Wood elected president of National Constructors Association for 1959. Wood is head of Girdler Construction Division, Chemetron Corp., Louisville, Kentucky.

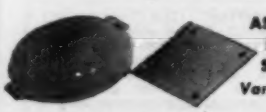
William A. Ackerman appointed refinery engineer at Sun Oil, Marcus Hook, Pa. He succeeds **Frank W. Bowen** who moves up to assistant to the vice president in charge of manufacturing. **Jack A. Guthrie** succeeds Ackerman as manager of the Technical Service Division.

A. J. Hebsacker becomes regional supervisor, Chemical Processing Division, Detrex Chemical Industries.

NECROLOGY

Roy E. O'Brien, 60, field secretary of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Salt Lake City. O'Brien was formerly with Mountain City Copper Company.

Samuel Zerfoss, 46, Chief of the Refractories Section of the National Bureau of Standards.



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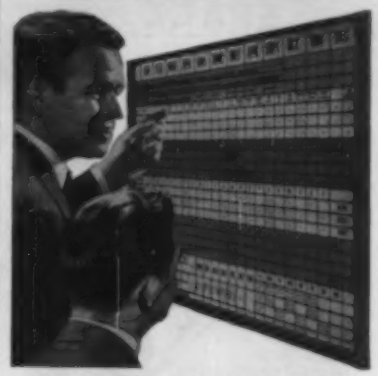

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News and Notes of A.I.Ch.E.

10% = $30,000: As of this writing, February 19, A.I.Ch.E. has reached 90% of its quota of $300,000 in the Member Giving Campaign. This is an extremely good record, and the campaign chairmen—president D. L. Katz and past presidents S. D. Kirkpatrick and W. G. Whitman—are to be congratulated on a wonderful job, as are all the Local Section campaign chairmen. The A.I.Ch.E. sections that have gone over the top total 16.

At the time of the Atlantic City meeting, we hope to announce the attainment of the full quota, and Local Section chairmen who have not closed their campaigns are being urged to make one more concerted effort to bring in the additional $30,000 needed. If you have not given and do not know the name of the individual in your area who is collecting these funds, please send your check to headquarters in New York, and your section will be credited with your contribution.

Close on our heels in the campaign is the American Institute of Electrical Engineers, which has collected $674,000, or 75% of its pledge.

National Bureau of Standards has asked A.I.Ch.E. to appoint representatives to advisory committees to help the Scientific Divisions of the National Bureau of Standards. Four programs are involved: one in high temperatures and transport phenomena, one in building materials, and two in cryogenic research. Appointed by Council for these posts were G. C. Williams of M.I.T.; Dean Warren McCabe of Brooklyn Polytech; Allen Latham, Jr., of Arthur D. Little; and Clyde McKinley of Air Products.

Summer Instrumentation Conference: Along with the Federation for Instrumentation Education and Research, the A.I.Ch.E. will sponsor this summer a three weeks' conference for college-level teachers of chemical engineering in process-control dynamics. A grant has been made by the National Science Foundation to cover the tuition and expenses of twenty-five teachers of chemical engineering. Lloyd Slater, Secretary of F.I.E.R., and Dave Boyd, of A.I.Ch.E.'s Subcommittee on Process Control, were the spark plugs of the idea. The course will be held at Case Institute, which will select the participants from a list developed by F.I.E.R. and A.I.Ch.E. of instructors from A.I.Ch.E.--accredited schools.

Affiliation Plan: The Institute of Radio Engineers has approved the plan for members of A.I.Ch.E. to affiliate with and receive the publications of I.R.E. professional groups without having to join I.R.E.

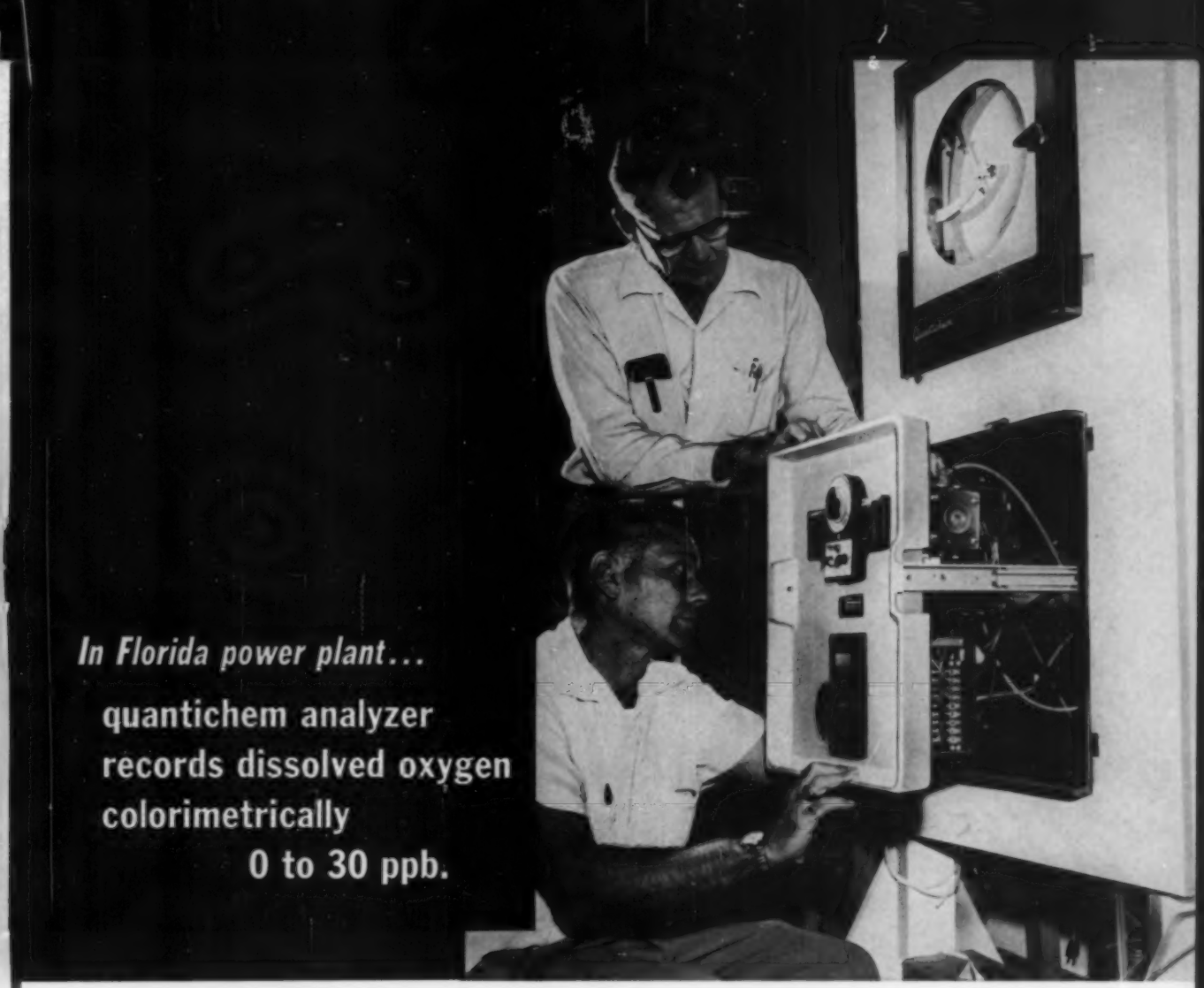
Standard Testing Procedures—Equipment Testing Procedures Committee has just had two standards recently approved by Council—a standard testing procedure for centrifugal pumps and a standard testing procedure on impeller-type mixers. Both these will be published soon. J. Y. Oldshue is chairman of the Subcommittee on Mixers.

Communication—Jerry McAfee is planning a Sections Activities Committee meeting in Kansas City in May, at which we hope to have reports from committee chairmen of the Institute to present to the Local Section representatives. This is part of a drive to have information about the excellent services rendered by A.I.Ch.E. to the membership become better known and used by the members.

TV and Ch.E.—Our Chicago Local Section, under G. E. Baille, is in the middle of an important public relations effort—telling the public all about chemical engineering over TV

Channel 11 in Chicago. John E. Anderson is chairman of the Local Section Committee which will put on six half-hour, company-sponsored, programs entitled "The Chemical Engineer's Program." It will be on the air from 9:30 to 10:00 P.M. the first Thursday of each month, will explore the work of chemical engineers in petroleum, plastics, food, steel and atomic energy.

F.J.V.A.



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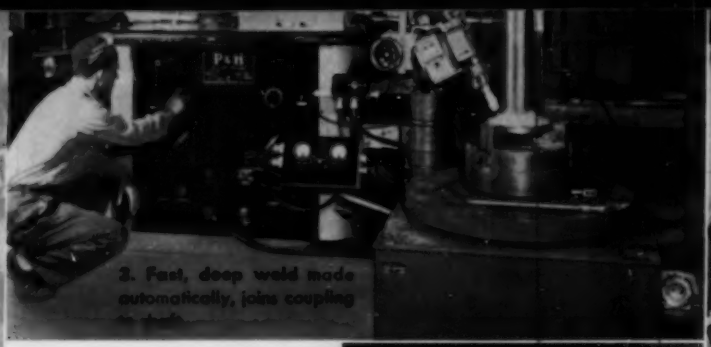

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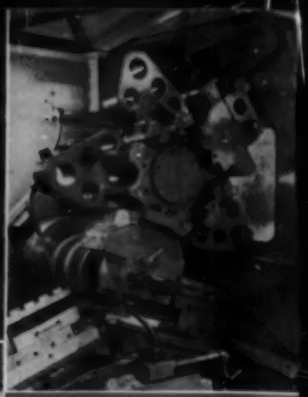

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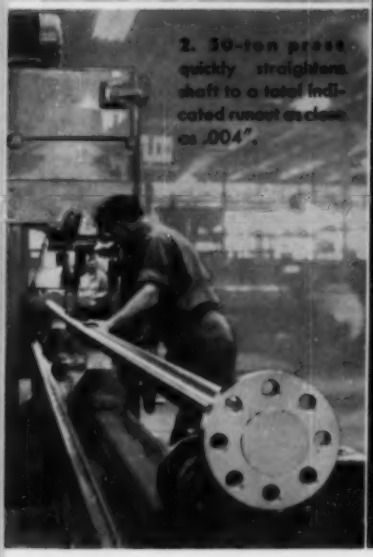
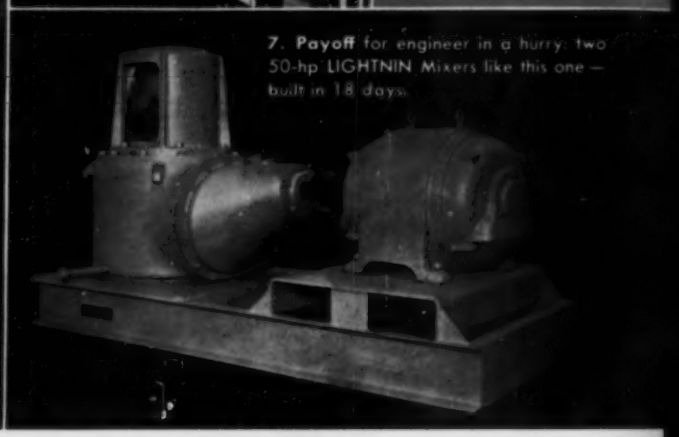
6. Drill makes 12 holes at once in a mixer mounting flange.

4. Mass assembly—but every mixer is a custom job.



2. 30-ton press quickly straightens shaft to a total indicated runout as close as .004".



7. Payoff for engineer in a hurry: two 50-hp LIGHTNIN Mixers like this one—built in 18 days.

How to chop thirteen weeks off a startup date

Hustling a new process into being, engineers at a large chemical plant were really pressed for time.

Needed almost immediately to meet the production deadline were two large heavy-duty fluid mixers.

The new process was nearly ready to go. A long wait would mean soaring standby expense, lost income, a decisive edge for competition. And the usual manufacturing time for the mixers they needed was *16 weeks.*

One of the engineers phoned a LIGHTNIN Mixer representative. He, in turn, phoned the MIXCO factory. How soon could we ship two 50-horsepower LIGHTNIN Mixers (see figure 7), each equipped with a turbine impeller big as a dining-room table on a shaft 18 feet long, 4½ inches in diameter? And could we supply the lower shafts and impellers *with* rubber covering?

Six tons in 18 days

His call set off a swift, far-reaching chain reaction. Just 18 days later, we put nearly six tons of mixers aboard a fast truck. Both units were completed and shipped *thirteen weeks ahead of normal.*

Magic? No—just speed. We're set up for it because we build nothing but mixers. We build them fast when you need them fast—because we stock a tremendous range of mixer components and parts, in materials that match just about any process requirement. And we have the manpower, the machines, and the know-how to give you the right answer to *any* fluid mixing problem. Rapidly.

For competent engineering help, call your LIGHTNIN Mixer representative (listed in Chemical Engineering Catalog). Or write, wire, or phone us direct.

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